MONTHLY WEATHER REVIEW.

Editor: Prof. CLEVELAND ABBE. Assistant Editor: CLEVELAND ABBE, jr.

VOL. XXXVII. APRIL, 1909. No. 4

The MONTHLY WEATHER REVIEW summarizes the current manuscript data received from about 3,500 land stations in the United States and about 1,250 ocean vessels; it also gives the general results of the study of daily weather maps based on telegrams or cablegrams from about 200 North American and 40 European, Asiatic, and oceanic stations.

The hearty interest shown by all observers and correspondents is gratefully recognized.

Acknowledgment is also made of the specific cooperation of the following chiefs of independent, local, or governmental services: R. F. Stupart, Esq., Director of the Meteorological Service of the Dominion of Canada; Señor Manuel E. Pastrana, Director of the Central Meteorological and Magnetic Observatory of Mexico; Señor Camilo A. Gonzales, Director-General of Mexican Telegraphs; Capt. S. I. Kimball, General Superintendent of the United States Life-Saving Service; Commandant Francisco S. Chaves, Director of the Meteorological Service of the Azores, Ponta Delgada, St. Michaels, Azores; Dr. W. N. Shaw, Director of the Meteorological Office, London; Maxwell Hall, Esq., Government Meteorologist, Kingston, Jamaica; Rev. L. Gangoiti, Director of the Meteorological Observatory of Belen College, Habana, Cuba; Señor Luis G. y Carbonell, Director, Meteorological Service of Cuba, Habana, Cuba; Rev. José Algué, S. J., Director of the Phillipine Weather Bureau, Manila; Maj. Gen. M. A. Rykachef, Director of the Physical Central Observatory, St. Petersburg, Russia; Carl Ryder, Director, Danish Meteorological Institute, Copenhagen, Denmark.

As far as practicable the time of the seventy-fifth meridian is used in the text of the MONTHLY WEATHER REVIEW.

Barometric pressures, both at land stations and on ocean vessels, whether station pressures or sea-level pressures, are reduced, or assumed to be reduced, to standard gravity, as well as corrected for all instrumental peculiarities, so that they express pressure in the standard international system of measures, namely, by the height of an equivalent column of mercury at 32° Fahrenheit, under the standard force, i. e., apparent gravity at sea-level and latitude 45°.

FORECASTS AND WARNINGS.

By Prof. E. B. GARRIOTT, in charge of Forecast Division.

Barometric movements over the Northern Hemisphere were unusually rapid during April, 1909. In the Asiatic area the alternations of high and low pressure were quite regular and the intervals between the crests and troughs averaged, respectively, about five days. During the first decade of the month high barometer and settled fair weather prevailed over west-central Europe. During the second decade and until the closing days of the month, however, there was a rapid succession of barometric disturbances over that region. The Atlantic and Pacific areas also showed a rather uniform succession of high and low pressure.

In the United States the month was marked by periods of unusually low temperature, and at its close the line of freezing weather was traced from the upper Lake region to New Mexico and snow was falling in the upper Lake region and upper Mississippi Valley. From the 5th to the 8th a storm of marked intensity advanced from the southern Plateau to the St. Lawrence Valley, attended by snow in the middle Rocky Mountain districts and by heavy rain from the States of the lower Missouri Valley over the Ohio Valley and the Gulf and Atlantic coast States, and by severe windstorms from the Southwest over the Great Lakes and the Middle Atlantic and New England States. On the 7th the following special forecast was issued:

> Several days of comparatively cool weather are indicated for the eastern half of the United States, with frost in the middle and upper Mississippi and Ohio valleys and the Lake region, and thence over the Middle Atlantic and New England States. Frost is also likely to occur in the interior of the Gulf and South Atlantic States.

Following the disturbance of the 5–8th an area of high barometer swept south and east from the British Northwest Territory attended by frost-bearing temperatures that reached the west Gulf States the morning of the 9th and covered the east Gulf and Atlantic States the morning of the 10th. On that date frosts were general in the South, including northwestern Florida, and on the morning of the 11th the minimum reading of 26° was noted at Washington, D. C. The principal storms of the second decade of the month advanced from the middle Rocky Mountain region to the north Atlantic coast from the 11th to the 14th, and from the 17th to the 19th. The storm of the 11–14th was attended by heavy snow in the middle Rocky Mountain districts, by heavy rain in districts east of the Rockies, and was followed by a cool wave that caused frost in central portions of Louisiana and Mississippi. A storm that advanced from the middle Rocky Mountains to the Lake region from the 20th to the 22d was attended by heavy snow and was followed the night of the 22–23d by frost in Colorado. On the 21st a warning of freezing temperature was issued for that section and on the morning of the 23d the temperature fell to 27° at Pueblo and in the Arkansas Valley. The Star-Journal, Pueblo, Colo., of April 23, 1909, comments as follows regarding the frost:

> The Weather Bureau predicted the frost more than twenty-four hours ahead and every effort was made to give the warning to the farmers. Almost without exception fruit growers whose crops were endangered heeded the warning of the Weather Bureau and protected every early-blooming fruit tree with plenty of smudge fires and so prevented any loss by frost.

From the 28th to the 30th a storm of exceptional severity advanced from the middle Rocky Mountain region to the Great Lakes, attended by snow in northern districts from the Rocky Mountains to New England, and by heavy rain, high winds, and severe local storms in the central valleys and the Lake region. Following this disturbance a period of unseasonably cold weather set in over the country generally east of the Rocky Mountains.

BOSTON FORECAST DISTRICT.*

[New England.]

Temperature was somewhat below normal in Maine, New Hampshire, and Vermont and slightly above normal in the three southern States. Precipitation was generally above normal, the excess ranging from 1 inch to 2 inches in northern portions to 2 and 3 inches in Rhode Island and Connecticut. Snowfall in measurable amounts was quite general, except in

Massachusetts and Rhode Island, where there was very little. The greatest amount for the month was 30 inches, at Patten, Me. There were no prolonged and destructive gales and no great delay to shipping from stress of weather. There were no storms without warnings.—*J. W. Smith, District Forecaster.*

NEW ORLEANS FORECAST DISTRICT.*

[Louisiana, Texas, Oklahoma, and Arkansas.]

Temperature was generally below the normal, and, except over eastern portions of Louisiana and Arkansas, precipitation was deficient. Frost warnings were issued on eleven dates, and warnings were issued for all frosts that occurred in the apple-growing section of Arkansas. High winds occurred over the interior on the 6th and 30th, forecasts for which were issued on the previous dates, and strong winds occurred along the Gulf coast on a few dates, for which warning had, as a rule, been issued.—*I. M. Cline, District Forecaster.*

LOUISVILLE FORECAST DISTRICT.*

[Kentucky and Tennessee.]

With the exception of two quite warm periods, the 4–6th and 16th–21st, unusually cold weather predominated, with frequent frosts in the first and last decades of the month. Frost warnings were issued on seven occasions, but damage was confined mostly to the first decade. Precipitation was in excess, and over much of Kentucky it was nearly double the normal amount. There were four rain periods and many thunderstorms, a number of which were attended by violent wind squalls and excessive rains. There was also considerable destruction by lightning. The storm of the 29–30th was of unusual severity and the damage by wind and water extensive. —*F. J. Walz, District Forecaster.*

CHICAGO FORECAST DISTRICT.*

[Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas, and Montana.]

Precipitation was above the average over the eastern half and below normal over the western section of the district, while temperature was quite generally below the average, the deficiency in the Northwest being considerable. Storms crossed the district with great frequency, causing the excess of rainfall above referred to in the eastern section. Four of the storms were attended by high winds. The first reached the Lake region the night of the 6th and crossed it during the 7th. Storms also crossed the Lakes during the 11–12th, 21st, 29–30th. The usual advices were sent to open ports in connection with the first storm mentioned, and storm warnings were ordered after the 10th, when the storm-warning season began. Frost warnings were issued for several days for Illinois, Indiana, Missouri, and Kansas, and when exceptionally low temperatures seemed imminent for the Northern States special forecasts for temperatures of freezing or below were made.—*H. J. Cox, Professor and District Forecaster.*

DENVER FORECAST DISTRICT.*

[Wyoming, Colorado, Utah, New Mexico, and Arizona.]

Except in southern portions of Arizona and New Mexico, the weather was cooler than usual. Precipitation was in excess in north-central and northwestern Colorado and deficient in other portions of the district. In southern New Mexico and southern Arizona no rain fell. Following the passage of areas of low pressure, the weather was decidedly cold over the greater portion of the district on the 5–8th, 11–12th, 20th–23d, and 29–30th. On the morning of the 30th a destructive frost occurred in Wyoming, Utah, Colorado, and northern portions of New Mexico and Arizona. All important weather conditions were covered by the forecasts.—*P. McDonough, Local Forecaster.*

SAN FRANCISCO FORECAST DISTRICT.†

[California and Nevada.]

The month was abnormally dry. No storms crossed the State from the ocean and there were no southerly extensions of North Pacific low areas. Unusually warm weather prevailed over southern California at the beginning of the month. A few thunderstorms were reported in the mountain districts on the 28th. There were no frost nor storm warnings issued during the month—*Alexander G. McAdie, Professor of Meteorology.*

PORTLAND, OREG., FORECAST DISTRICT.†

[Oregon, Washington, and Idaho.]

The month was cool and dry, with frequent frosty mornings. Warnings were issued for practically all the frost that occurred. The interest taken in frost warnings is constantly increasing and more smudging was done this year than ever before. There are still, however, large fruit sections in the district where no attempt is made to protect the crops from frost by any of the methods in vogue. A new method of smudging, which consists of placing a large number of small pots in the orchard and burning crude petroleum in them, has been tried. Fires thus produced make a dense smoke and heat to some extent the surrounding air, and it is claimed that the plan has been very successful.—*E. A. Beals, District Forecaster.*

RIVERS AND FLOODS.

The month was characterized by the usual seasonal floods east of the Mississippi River, but none of them was in any way marked, except in portions of New England, where warm rains and melted snow and ice on the 6th and 7th caused a decided rise in all the rivers, with considerable resulting damage. Flood stages were general along the Connecticut River, with a crest of 19.1 feet, 3.1 feet above flood stage, at Hartford, Conn., on the 10th. Similar conditions on the 13th and 14th caused a second and more pronounced rise, with a crest stage of 24.7 feet at Hartford, on the 17th. All the tributary streams in northern New Hampshire, northern Vermont, and western Maine were in flood, and much damage of the usual character resulted. Warnings were issued whenever possible, and through them a large amount of portable property was saved. Warnings were also issued during the latter half of the month for the moderate floods in the Susquehanna and James rivers. The damage was insignificant, and property to the amount of $10,000 was saved along the James River.

Over the Black Warrior and lower Tombigbee watersheds heavy rains from the 22d to the 27th, inclusive, were followed by a flood of considerable proportions, beginning on the 26th and continuing through the early days of the following month. On the 1st day of May the stage of the river at Demopolis, Ala., was 50 feet, 15 feet above flood stage, with a further rise of 1.2 feet indicated. The first warnings were issued on the 24th, and supplementary ones frequently thereafter. The losses amounted to about $40,000, about equally divided between crops and suspension of farm and other work. To the lumber interests the flood was very welcome, as it permitted the movement of a large quantity of logs. Losses by erosion were offset by alluvial deposits. The value of property saved through the Weather Bureau warnings was about $200,000.

In the Pearl and Pascagoula rivers the floods were more moderate, with losses amounting to about $12,500, and property saved to the value of about $10,000.

Nothing of special interest occurred along the three great rivers of the interior. There was a moderate flood in the Mississippi River in the vicinity of Hannibal, Mo., beginning on April 12 and lasting well into May, but little or no damage resulted. A sharp rise set in over the upper Ohio and tributaries on the last day of the month, and on the morning of May 1 a moderate flood was in progress.

ICE.

No ice was reported on the 11th day of the month, when the Penobscot River opened at Mattawamkeag, Me. The Connecticut River at Wells River, Vt., opened on the 5th, and the

* Morning forecasts made at district center, night forecasts made at Washington, D. C.

† Morning and night forecasts made at district center.

Missouri River at Wolf Point, Mont., and the Mississippi River at Fort Ripley, Minn., on the 6th.

The highest and lowest water, mean stage, and monthly range at 216 river stations are given in Table VI. Hydrographs for typical points on seven principal rivers are shown on Chart I. The stations selected for charting are Keokuk, St. Louis, Memphis, Vicksburg, and New Orleans, on the Mississippi; Cincinnati and Cairo, on the Ohio; Nashville, on the Cumberland; Johnsonville, on the Tennessee; Kansas City, on the Missouri; Little Rock, on the Arkansas; and Shreveport, on the Red.—*H. C. Frankenfield, Professor of Meteorology.*

SPECIAL ARTICLES, NOTES, AND EXTRACTS.

THE CLOUDS OF VENUS AND THEIR SIGNIFICANCE.[1]

By ARTHUR W. CLAYDEN, M. A.

If it be assumed that the visible surface of Venus is the outer face of a heavily cloud-laden atmosphere, comparable in mass and composition with our own, it seems that certain deductions may be based on its observed features which have not hitherto been pointed out, though they convey valuable hints as to the planet's physical condition, the position of its axis, and the period of rotation.

There is no need to recapitulate here the many reasons for believing that the surface visible to most telescopes is actually cloud, and the sequel will show that such a view is not incompatible with the detection of sharp markings such as have been described by specially favored observers. My own observations have been made with the 6.8 inch refractor by Tully, described in Vol. II of the Society's Memoirs. Its long focus (144 inches) gives excellent definition of Jupiter and Saturn, when the seeing is good, with powers up to 450; but it has never shown me anything on Venus which does not seem easily explicable on the assumption that the planet is shrouded in clouds, and that its atmosphere bears something like the same relation to its mass as our own atmosphere does to the earth's.

Taking this for granted, let us consider how those clouds should be distributed according to different views as to the period of rotation and the position of the polar axis.

LONG ROTATION PERIOD.

First let us assume that the axis makes a large angle with the plane of the orbit, and that the period of rotation is coincident with the revolution. That is to say, that the planet always turns the same face to the sun—one side always exposed to the solar glare, and the other feeling the full effect of continuous radiation into space.

In this case, even allowing for considerable libration, it is more than difficult to imagine how the clouds are maintained on the sunlit face at all. The whole of the water should long ago have been distilled on to the dark side, and there locked up in the form of ice. It seems impossible that there should be an atmospheric circulation capable of keeping up a high enough temperature on the cold hemisphere to allow of the return to the hot one of a sufficiently large amount of water to produce the clouds. We can not call to our aid a circulation of water in the liquid state, for rivers are dependent upon rainfall or thawing ice, and the very seas should have been distilled. A slow glacial creep seems the only possibility, and that could hardly suffice to do more than produce a ring of cloud along the terminator, leaving the greater part of the hot hemisphere to stand out naked to the sunshine and to our view. Moreover, the phenomena seen along the terminator show no symptoms of great and rapid movements of the atmosphere, such as should certainly be the case if the continuity of a reasonable balance of temperature, and therefore of humidity, were dependent even indirectly upon them.

It may be contended with some reason that the great pall of clouds will moderate the temperature of the sunlit face, but this hemisphere must, on the whole, be one of rising convection currents, while the dark side must conversely be one of descending currents. Descending movements mean clear skies, and therefore unchecked radiation; so, whatever the initial temperature of the dark face may have been when last shut off from the sun's heat, it can not have been protected by a blanket of cloud, and must be intensely cold.

The assumption of a high internal temperature is no more satisfactory, for the same causes which should have frozen the water should have previously chilled the solid rocks, and have thereby placed a thick protecting shield between the hot interior and the frozen surface. If we allow for the difference in the internal pressures, the densities of Venus and the earth are so near as to imply not only identity of composition but a close similarity of condition.

It seems that the only way in which the persistence of the cloudy envelope could be explained, would be to assume a thermal conductivity for the mass of the solid planet far higher than that of the materials of the earth.

In the absence of any such extravagant and improbable supposition, it thus appears that the continued existence of the cloudy shell affords an almost conclusive negative to the possibility of an exact identity between rotation and revolution.

SHORT ROTATION PERIOD.

Next, suppose the axis to make a large angle with the plane of the orbit, and that the rotation period is not very different from the length of a terrestrial day.

In this case it is at once obvious that the distribution of temperature on the planet should be strictly similar to that on the earth. The actual values might be everywhere higher, but the gradients should be in precisely the same directions. Of course the local variations due to the distribution of land and water would differ, but the broad differences due to latitude and the time of day should present an exact parallel.

Moreover, the laws of motion which govern the movements of our atmosphere, and combine with the results of the temperature gradients to determine the general arrangement of atmospheric pressure and the great wind systems, must inevitably produce effects on the somewhat smaller planet, just like those which dominate the meteorology of the earth.

The region of ascending or cloud-producing currents must be similarly distributed, and the descending or cloud-destroying currents must occupy the same relative places.

The result should be a belt of uprising currents surrounding the planet's equator at its equinoxes, and moving more or less toward each pole in turn with the progress of the seasons. North and south of this, at about the latitude of 20° or 30°, there should be a belt of higher pressure, and therefore of descending motion, while farther away from the equator toward each pole the chief drift of the atmosphere should be tangential and moving with the rotation.

There should therefore be a shining white belt over the equatorial low pressure, flanked on either side by a band where clouds should be small and scanty, and therefore much less brilliant. Then again, brighter regions should extend to each pole.

Moreover, such a circulation should give rise to storms analogous to our own, moving over the planet in the same way, and their courses should often be clearly visible.

The earth must show all these features so plainly that they would be the first thing noticed. Except in the region of our tropical belts of high pressure an astronomer on Venus would

[1] Reprinted, by permission, from the Monthly Notices of the Royal Astronomical Society, January, 1909, 69:195-204, and accompanied by illustrations [Chart IX] from sketches by the author.

rarely be able to make out much of terrestrial geography. The belt of clouds marking the position of the equatorial rainy season must stand out as a shining white band, in strong contrast with the darker belts on either side. All details of the world's temperate zones must be masked in the most annoying way, for it must be very rare that a district so large as the British Isles is entirely free from cloud, even if we exclude cirrus from consideration.

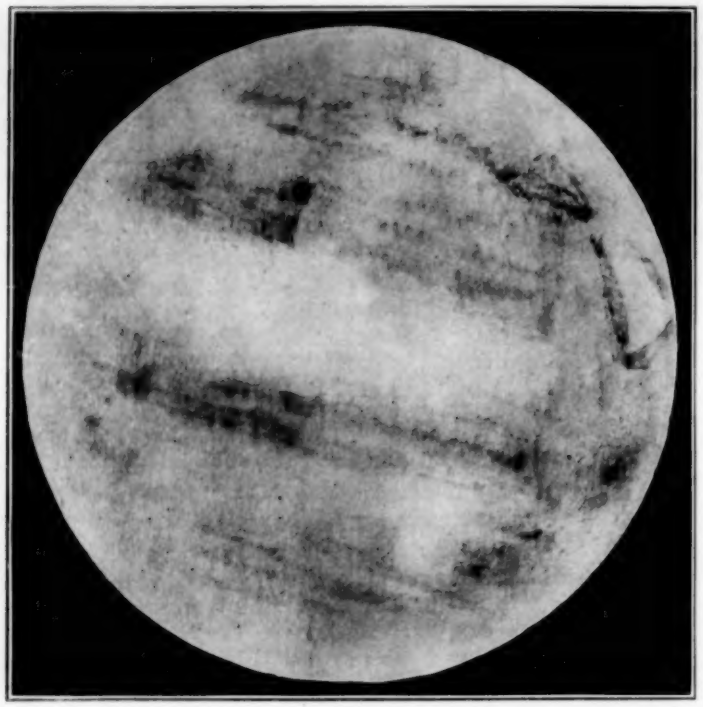

FIG. 1.—The earth (a belted planet) as it would appear from Venus.

In fig. 1 we have a view of the earth as it would probably appear to an astronomer on Venus, but the parts of the oceans visible would be tinted with a pale shade of indigo, while the land surfaces would be tinged with shades of ruddy brown or dark green, thereby adding to the contrasts.

There is no question that the earth is a belted planet; and if Venus had a rotation period comparable with our day, and if the atmosphere is of similar or greater density than ours (which is essential for the formation of the shell of convection clouds), she also would take a place in the same group. It is true that Mars does not, but its small mass and the low value of gravity are sufficient to account for the absence of the lower clouds, and these are those which form the belts.

There seems, therefore, no reasonable doubt that if the polar axis of Venus forms a large angle with the plane of her orbit, her rotation period can not be anything like so short as the length of our own day. In Chart IX, fig. 2, we see the sort of shading which the planet ought to show under such circumstances.

Suppose, next, that the axis is very little inclined to the plane of the orbit, as has been sometimes suggested. Apart from all mechanical difficulties in the way of such a supposition, the behavior of the cloud stratum affords a sufficient test. Each pole will in turn be heated and cooled, so the general distribution of temperature will be different. But at each equinox the temperature gradients should be in directions similar to those presented in the last case. From the equator toward the pole last presented to the sun the gradient would be small, but it would be very steep toward the other. The planet should therefore show a bright equatorial band shading away toward the warmer pole, and flanked on the side toward the colder pole by a clearly marked dark belt. Chart IX, fig. 3, shows the planet as it should appear under these circumstances, supposing the axis to be inclined about 35° to the ecliptic and the warmer pole to be inclined toward the observer. That it does not show a trace of any such feature, or any other symptom similar to the former case, is a sufficient proof that the supposition is not a fact.

It thus appears that the short rotation period can not be true in any position of the axis, and that the planet's day and year can not be identical. In one case we ought to see things which we do not, and in the other we ought not to see what we do.

THE MOST PROBABLE PERIOD.

The objections to a short period are equally valid for any period shorter than our own day, and for any period longer than the earth's up to one as long probably as our week or more, but the difficulty with the long period is only applicable to exact identity between the planet's day and year. If the actual length of its day falls only a little short of the time of revolution, all parts of its surface will in turn experience the extremes of heat and cold. Probably any period between 20 of our days on the one hand and, say, 180 or 200 days on the other, would give conditions in which no cloud bands or high-pressure tropical belts would be produced parallel to the equator and no permanent locking up of the water could occur.

The estimates made, with the exception of Bianchini's 24 days 8 hours, all indicate a period similar to our own day, or one nearing the length of the planet's year. If the markings upon which these measurements were based were actual features of the planet, or effects produced upon the clouds by underlying features, and not mere atmospheric phenomena owing their position to the time of day or drifting wind, it seems most probable that Venus rotates upon her axis in a time which approaches the length of her year, but differs from it sufficiently to enable water to be carried across the sunlit face without complete evaporation.

Upon this supposition, it seems easy to explain several of the best known and most easily observed phenomena presented by the planet in its different phases, including that error of phase which has not hitherto received any satisfactory interpretation.

Suppose, then, that the axis is highly inclined to the plane of the orbit, and that the rotation period is long—so long that the law of equal areas, Ferrel's law of the deflection of currents moving over a rotating body, and the law of centrifugal force do not exercise any dominating effect on the atmospheric circulation.

Under these circumstances, temperature on the sunlit face will be lowest at the poles and along the sunrise terminator. It will increase to a maximum at a point on the equator west of the noon meridian, and will decrease toward sunset and across the dark side until the day is again breaking. The hottest region will not be a belt, but an oval area with a steep gradient of falling temperature toward the poles and sunrise terminator and a gentler gradient toward the sunset.

There should be, therefore, a region of expansion over the hottest area, from which the upper layers of the air should flow radially outwards in all directions, following the gradients of decreasing temperature, exactly as our atmosphere overflows from the equatorial low-pressure belt to the Tropics.

Just as the terrestrial overflow results in the overloading of the lower air along the two anticyclonic belts of Cancer and Capricorn, so in the case of Venus the radial overflow must create a ring of higher pressure about 30° or 40° away from the maximum temperature, and therefore low pressure, on every side.

In the case of the earth the bands are irregular, and frequently incomplete, owing to the distribution of land and

water. This would probably be the case with Venus. The exact position and intensity of the high-pressure ring should vary slightly from time to time as the diverse hidden features of the planet pass beneath it on their journey across the disk. Nevertheless, it should always be there and, from the difference in temperature gradients toward sunrise and sunset, it should be much more marked on the morning side than on the other. In our own atmosphere[2] we have in the constant small rise of the barometer between 9 and 10 a. m. a clear indication of a similar tendency to the formation of a ring of high pressure around the areas of greatest heat.

Beyond the high-pressure ring there should be a fall of pressure toward the terminator on every side into the darkness, but the pressure should rapidly increase again to a great maximum covering a large part of the dark hemisphere.

Low-pressure regions mean ascending currents and the abundant formation of convection clouds of the cumulus, cumulus-nimbus, and cyclonic types. High-pressure regions, on the other hand, mean descending movements and scanty formation of convection clouds. Even when the sunshine does produce local ascending currents in such a region, they are stunted by having to rise against the general descent, and the cumulus clouds produced are small and scattered, leaving wide interspaces through which descent goes on.

The whole area on the face of Venus within the high-pressure ring should be covered with ascending cloud columns; and if moisture is abundant enough, a dense mass of convection clouds like those which accompany our equatorial rains, should reach high up above the body of the planet.

The high-pressure ring should be checkered with smaller detached cumulus, like those of our trade wind zones, less brilliant because deeper down, and because the interspaces should let us see still deeper, even perhaps to the shaded surface of the planet itself. Here, if anywhere, there would be the best chance for us to glimpse something of the planetary geography, but any markings would look as if seen through a luminous mist caused by the detached clouds.

Beyond this ring of lesser brightness the convection clouds should again rise above the surface, but should rapidly lessen in altitude as the terminator is approached.

At eastern elongation the terminator is probably sunrise and the clouds are growing. As they are carried slowly forward into the day they should rise higher and higher. On reaching the high-pressure ring they would be degraded, broken, and perhaps to a great extent destroyed. But beyond this they would be reinforced by still stronger convection until the hottest region had been crossed. From this point degradation should again set in, and toward sunset there would be a rapid fall in their level, so that their upper surfaces should slope rapidly downward into the night.

Now, convection currents rising from the ground do not lift their burden of cloud particles indefinitely. The very formation of the cloud, by loading the air with particles of liquid water or solid ice, tends to check the ascent, and the thermal effects of expansion, with the fall of rain and hail, combine to put a limit to their possible stature. On the earth they do not reach beyond 5 or 6 miles from the ground.

But the sun's rays falling on the upper surface of a stratum of such clouds evaporates water from them, and this is carried upward by the general ascent of the air over a low-pressure area until it reaches such altitudes as 9 or 10 miles, or more. Here it condenses into fine particles of ice, and forms the great variety of translucent clouds classed as cirrus and cirro-nebula[3].

When we bear in mind the greater intensity of solar radiation on Venus, we see that both convection from the ground and this upper circulation should take place on a grander scale than anything we experience. Its atmosphere should probably be richer in water vapor, both classes of cloud should be more abundant, and, owing to the smaller value of gravity, the altitudes reached should be greater.

Since atmospheric pressure should, on the whole, be considerably greater on the dark side than on the one turned toward the sun, the upper currents should flow from the hot side over the high-pressure ring and toward the terminator, while colder under currents should flow in the opposite direction.

The cirrus clouds floating in the upper currents should thus pass constantly across the terminator on all sides, and persist some distance beyond. They are always thin, and generally scattered. If the base of the atmosphere on Venus is at a higher temperature than is the case with the earth, a supposition which is almost certainly true of the greater part of the sunlit face, cirrus clouds should not form until an altitude is reached at which the pressure is lower than that required for their formation here. They should, therefore, be loftier and even thinner than ours, and ours do not hide the sun. They are shining white by transmitted light, and shine most brilliantly when viewed edgewise.

The whole sunlit face of Venus should thus be covered with a delicate, filmy network of cirrus, similar to that which enfolds the earth, varying in density and transparent as a whole when viewed at a considerable angle, but becoming whiter and more opaque as the obliquity of the point of view increases.

Observational evidence.

Now there are certain distinct phenomena which have been repeatedly described, and which may be seen under suitable circumstances with quite moderate telescopes, which seem to me to admit of simple explanation if the foregoing hypotheses are correct.

1. The brightening of the limb relative to the rest of the disk.

This is a distinctive feature of all planetary bodies which may be reasonably supposed to have at most a thin, pure atmosphere above the reflecting surface.

In the case of Venus it may be explained as due in the first instance to the fragmentary veil of cirrus, which stands out more and more brilliant as it is seen more obliquely. Being higher in the atmosphere its particles would be brighter, area for area, than those of the lower clouds, whose summits would be seen through a greater thickness of air, and would also to some extent be shaded by the cirrus itself.

If the cirrus sphere could exist in space alone, we should see only a slender ring of light, very lustrous on its external margin, but rapidly fading away to a dark interior.

2. The prolongation of the cusps.

If the cirrus veil is, as would almost certainly be the case, some miles above the convection clouds, it would catch the light several degrees beyond the true terminator. Since the air at such an altitude is practically free from dust, and since all the lower layers of the atmosphere are densely laden with opaque cloud, we can not expect that even the tips of the horns should be illuminated by sunset coloring. This can only be produced when the rays have passed through the lower air. The light should therefore be sensibly white, or at most a pale yellow. The thinning of the cusp to a fine, sharp line would be due to the fact that as the intensity of illumination diminishes with distance from the true terminator, the film of cirrus will need to be seen more and more obliquely for a given brightness. It should, therefore, thin out exactly as it does.

3. Detached points beyond the tips of the horns, and occasional absence of the horns.

Cirrus clouds are not continuous. They do not form a con-

[2] See O. L. Fassig in Proc. 3d Convention, Weather Bureau officials, at Peoria, Ill., 1904. Washington, 1904. 8 vo. p. 117, fig. 4 and Chart I.—*C. A., jr.*

[3] Mr. Clayden designates as "cirro-nebula" the thin veil-like clouds which produce halos. It is much thinner and usually higher than cirro-stratus. See his "Cloud Studies," London, 1905. 8vo., pp. 24–28 and plates 3 and 4.—*C. A., jr.*

tinuous layer around the earth, nor is there any reason to suppose they should do so on Venus. Hence, if one of the clear spaces should happen to be in the right position, we should see through the gap, and the horn would be absent or broken.

Moreover it may be assumed that the planet is diversified by mountains and valleys like our own, and that these are probably of similar stature and depth.

When the great air-currents flow over such features, up and down movements are produced, which react upon any cloud zones above, destroying the clouds by a descent in one place, creating them or throwing them up to an abnormal height by an ascent elsewhere.

We can thus explain irregular or even periodic appearances of projections of the bright surface, or the occurrence of dark spaces in it, by attributing them to the passage of the cloud-laden air over an uneven surface beneath. Projecting points of light may well be thrown up to very great altitudes without needing to suppose mountains so vast that they would flatten out under their own weight.

4. The acceleration of phase in eastern elongation is commonly observed to vary from four to eight days—dichotomy, or any special phase, being so much earlier than the theoretical time.

This can only mean that the surface along the sunrise terminator is not at right angles to the planet's radius, but that it slopes upward toward the sun, and that the slope is steepest in the equatorial regions, and diminishes toward the poles.

But this is exactly how the upper surface of a shell of rising convection clouds should rise, and the fact alone is an almost conclusive proof that the cloud theory is right.

The phenomenon is not limited to dichotomy, but can be noticed at any time not far removed from greatest elongation.

The variation of the acceleration would imply a variation in the slope such as would be a natural consequence of changes in the underlying surface due to the slow rotation relative to the sun which has been postulated as essential to the permanent maintenance of the clouds.

5. The retardation of phase in western elongation is rather more pronounced. It can be explained as due to an even greater slope of the mean surface of the clouds, due to the collapse of the rising currents and breaking down of the clouds toward sunset. On the earth the fall of the cloud levels in the evening is distinctly more rapid than their morning rise. The fact may be regarded as a proof confirmatory of the last.

6. The shading off of the terminator and,

7. The variable contour of the terminator would both be the natural result of variations in the height to which the clouds had reached in consequence of differences in the nature, and therefore temperature or moisture of the surface beneath.

8. The smaller luminosity of the neighborhood of the terminator.

Apart from the glittering margin, which has been attributed to the cirrus veil, and apart from any definite darkening of a particular region, this is perhaps the most obvious feature of the planet.

At the limb we see only the shining cirrus. Elsewhere we look through it onto the summits of the convection clouds. If, as appears to be almost certain, the individual clouds have on the whole a roughly pyramidal or pillared contour like our cumulus and alto-cumulus castellatus, the body of the planet would be brightest near the limb, where only the tips of the clouds would be seen. On passing from the limb toward the center of the disk, we should see farther and farther into the shadows between them, and the proportion of shade should increase as the sun's rays become more oblique.

9. The presence of a faint band of shade, approximately parallel to, but at some distance from, the terminator.

This can nearly always be seen. It is not sharply contoured, but broad and ill-defined. Still a graduated shade, such as a neutral tint wedge, will generally bring it out. It is best seen in eastern elongation when the planet is near dichotomy, or approaching its maximum brilliancy. It varies from time to time in breadth and depth of shade, but always occupies the same position relative to the terminator. It can not apparently be followed into the shining ring near the limb. It has been described by M. Antoniadi in the Monthly Notices of the Royal Astronomical Society for March, 1898, and its appearance is shown in Chart IX, figs. 4 and 5, which are, of course, on different scales.

Surely this is a high-pressure ring, darker than the rest because we see deeper into it, and the spaces between the clouds are larger. It is much less pronounced in western elongation, as we should expect should be the case from the difference between the temperature gradients toward sunrise and sunset.

10. The mottling or granulation of the surface, the appearance of dark or bright spots moving over the terminator, and the occurrence of bright points beyond it, are all phenomena which should be visible, and receive obvious explanations.

11. The ring of light seen at inferior conjunction, and usually attributed to atmospheric refraction, would more probably be nothing but the edge of the illuminated shell of cirrus. This stratum would, everywhere around the terminator, be several miles above the clouds, and perhaps 10 or 20 miles above the actual surface of the planet. Mere refraction ought to give a ring of colored light, yellow, or even red. But if the lower air is, as has been supposed, blocked by heavy convection clouds, all colored rays would be stopped, while the high cirrus would shine with the silvery light we see.

At such altitudes atmospheric refraction would be almost negligible, and a calculation based upon the position in which the circle is complete would give the height at which these delicate structures float, if only we knew how much to allow for that rise of the lower clouds near the terminator to which we have attributed the error of phase.

The phenomenon, then, may be regarded as only another aspect of the same fact which also explains the prolongation of the cusps.

Finally, if we suppose that the convection clouds do not form a continuous sheet, but are distributed broadcast with clear intervals for the descending partial currents which should accompany them, it becomes easy to believe that under suitable circumstances and with sufficiently powerful optical means, it may sometimes be possible to penetrate the veil, and see at least some of the most salient features of the planet's actual surface. On the other hand, the underlying surface must react upon the clouds above, and it may well be that those sharply defined markings which have been recorded are nothing more than a result marked out upon the veil by the features hidden beneath.

THE MOON BLAMELESS.

We print in full the following letter to the New York Herald of May 31, 1909, from the prominent and popular French astronomer, Cammille Flammarion, as an influential contribution to the constant warfare between superstition and truth. While written particularly for the wine-growing districts of France, every word applies with equal force to the corresponding districts of this country. Even the general farmer would do well to consider the application of these simple and rational explanations to many of his problems and catastrophes.—*C. A. jr.*

OBSERVATORY OF JUVISY,
PARIS, FRANCE, *May 11, 1909.*

TO THE EDITOR OF THE HERALD:

The April moon again is astir with its peculiar influences. Radiant, warm afternoons, alluring as a tropical day almost, have been succeeded by nights quite as radiant, but as cold as in winter. At the end of April and the beginning of May we have been blessed with spring during the

day, followed by winter at night. From a medium temperature of 20°C while the sun shone we have experienced a fall of 9° or 10°, and the maximum of 25° has been followed by a minimum many degrees under zero in the nocturnal hours. Congestion in many cases has been caused by the heat at midday, and, on the other hand, in as many instances by the cold of midnight.

In every district where fruit is grown, and especially in the vine country, serious damage has been done by the unseasonable frost. In the champaign country the thermometer registered 5°C below zero during the first nights of May and the vineyards suffered severely. Those of Touraine and Anjou also were damaged, while from Bourgogne and from all points in the South of France we hear the same chorus of lamentation. Particularly malign in its influence this year, the April moon has scored innumerable victims in the vegetable world. The loss is estimated at many millions.

POOR MOON.

Poor moon! It will be difficult indeed to exonorate it after such an indictment. Yet is it more culpable, really, than its accusers?

As a matter of fact, what is the April moon? Generally, the definition that I gave a long time ago has been adopted; i. e., it is the moon which rises after Easter.

I gave this definition in consonance with the popular idea, contrary to the dictum of the Annual of the Bureau of Longitudes, because it is the only one which is acceptable. The definition of the Annual is, in effect, this:

"The name April moon is given to the moon which rises in its first quarter in April and is full either at the end of the month or, more ordinarily, in the early part of May."

Now the moon may rise in April, for instance, on the 1st, 2d, or 3d and be full neither at the end of the month nor in the beginning of May, for it would be a full moon the 15th, 16th, or 17th. Such a definition as that quoted is, therefore, not only not correct, but it implies a contradiction, and it may easily be seen what a degree of uncertainty and confusion may arise from it. In 1905 it is noted that the April moon appeared April 4, finishing its course May 4. This is in contradiction to the definition.

If any definition is to be held free from popular prejudice it certainly must be in harmony with its own terms. Gardeners, horticulturists, and all cultivators of the soil are imbued with this prejudice, because they fear the frosts of the last half of April and of the first two weeks of May. These are for them the most critical periods, which they believe are administered by the disastrous April moon and which, according to this definition, they have long associated with the feast of Easter. This festival is determined for the Sunday following the first full moon after March 21 (the spring equinox). Easter can not come before March 22, and the new moon following can not rise before April 5. In this definition of the April moon this lunation begins at its very earliest only on April 5 and ends on May 5, never beginning April 4, 3, 2, or 1. Yet generally, the full moon rises at the end of April or in the first days of May. When Easter is late (its date varies between March 22 and April 25), the April moon appears in May. Note particularly that Easter is determined and its date fixed by astronomy.

This year, 1909, the April moon appeared April 20 and was gone May 19. This lunation, so much dreaded, is not designed to arouse our fears, but it serves rather as a convenient point from which to contemplate a characteristic time of the year, that in which takes place the struggle of spring to overcome the last onslaughts of winter. *It is the change of seasons that is alone responsible for damage to vegetation, and every year it is the same so far as this phase of the year is concerned.*

TEMPERATURES ARE DIFFERENT.

If the night is clear there is a great deal of radiation from the earth into space, whence there results a sensible lowering of the temperature of the ground reaching many degrees below zero (centigrade), while the ambient air is maintained at a temperature some degrees above. It has been proved that objects can acquire in the nocturnal hours a temperature differing from that of the atmosphere which envelopes them. For example, if you suspend in the air in the evening small balls of cotton you will often find that their temperature is 6°, 7°, and even 8°C below that of the surrounding atmosphere. Vegetable growth is subject to the same effects. Thus a plant may be frozen hard while the thermometer hanging near by indicates a temperature much above 0°C.

When it is cloudy this phenomenon does not occur. The temperature of the atmosphere, the earth, plants, etc., remains the same. The clouds form a screen or veil and prevent the heat stored in the ground during the day from escaping and ascending toward the celestial vault at night. On the contrary, if no obstacle be opposed to it the nocturnal radiation dissipates the heat and the temperature of the ground is lowered rapidly. Soon the frost seizes in its cruel grip the plants that are still frail, the too delicate flowers and the young shoots on tree and shrub; the watery juices, which are very abundant in newly formed vegetable tissues, become frozen, are enlarged in volume and burst the receptacle in which they are contained. In the morning the solar rays caress the flowers and the buds mortally hurt by the cold of the night, giving them a pale yellow hue, which precedes their final dissolution in a very few days. The result would be the same if the moon did not exist. This is so true that sometimes a very simple precaution only is necessary to save the young cultures during this disastrous lunation; a veil of mist, a cloud of smoke, or even a little sheet of paper may serve as protection against the cold, perhaps averting a heavy loss.

To resume, let us say that the destruction of vegetation takes place when the atmosphere is transparent and the nocturnal radiation is intense. It is under the same circumstances, that is, when the heavens are serene and pure, that the moon sheds her white light upon the earth. But the moon is wholly innocent of the mischief that is attributed to her influence.

Moreover, the great thermometric variations that are observed, especially at this season of the year, attract our attention principally because of their grievous results. Nevertheless, such variations are to be noticed quite as much throughout the year. Ancient proverbs must not be taken too literally. For example, these three days, May 11, 12, and 13 are known by the names of the "saints of the ice," Saint Marmentius, Saint Pancras, and Saint Gervais. Now these saints of the ice are no more existent than the April moon, and the dates mentioned exhibit cold or warmth indifferently without any regularity. Neither in the one case or the other is there the least sign of an astronomical phenomenon.—*Camille Flammarion.*

SCIENTIFIC TRESPASS.

In his admirable address[1] on Earthquakes before the American Association of Geographers, Dr. G. K. Gilbert, as geologist, offered the following remarks, which apply equally well to meteorologists.

You are not to infer that an apology is made because I trespass on fields to which I have no title, for I am an advocate of the principle of scientific trespass. The specialist who forever stays at home and digs and delves within his private inclosure has all the advantages of intensive cultivation—except one; and the thing he misses is cross-fertilization. Trespass is one of the ways of securing cross-fertilization for his own crops and of carrying cross-fertilization to the paddock he invades. Hypotheses, the trial theories which compete for development into final theories, spring by the principle of analogy from earlier and successful theories, and the broader the investigator's knowledge of explanatory science the greater his opportunity to discover hypotheses that may be applied to his own problems. Progress is ever through the interaction of the sciences one on another; and scientific trespass is one of the profitable modes of interaction. The trespasser brings with him a mental attitude and a mental equipment which are new to the subject, and whether or no the idea he contributes eventually "makes good," its contribution creates a new category for observation and opens a new avenue of inquiry. And he carries back with him the pollen of new ideas.

WHAT IS THE CHINOOK WIND?

"The history of words is the history of the nation." The truth of this quotation from an early philologist is well exemplified by the following paragraph quoted from the Portland Oregonian:

In its present acceptation a "chinook" is the equatorial trade wind that blows during the winter months from the southwest and, laden with moisture, strikes the Pacific coast from the northern boundary of California to the Alaskan Archipelago. It is now the local name for the soft, balmy, south wind.

But it is a misnomer. In early days in Oregon, and even as late as the early seventies, our summer wind from the northwest was called a "chinook," so named because it blew into the Willamette Valley from the coast region inhabited by the Chinook Indians north of the entrance of the Columbia. Among the pioneers and their descendants a chinook wind was a "clearing up" wind. Now it signifies precisely the opposite, i. e., a wind from the south followed by rain.

Within the past twenty-five years the word has been grafted into the speech and the written language of the vast territory east of the Cascade Mountains, and circulates freely throughout Wyoming. It has been carried into western Nebraska. In recent years it has crept into Boston newspapers with local application. Any soft, balmy wind that springs up in winter is called a chinook.

Thus we see in an age of high civilization and universal knowledge the vicissitudes of written words. Within thirty years "chinook" has been turned "end for end."

The changes perpetually going on in the spelling of words are paralleled by equally radical changes in their meanings. The movement for simplified spelling represents the modern scientific, economical, labor-saving and socialistic spirit as contrasted with the individualistic, autocratic, and arbitrary spirit of the past generations. There is no continuous per-

[1] See Science, 1909, **29** (n. s.): 122.

manence in spelling or definitions. "The times change and we [the words] change with them." Hard and fast rules are wholly foreign to the spirit of growth that permeates every living language. Why should we unreasonably fetter the growth of that which is full of life and beauty. The lexicographer catches the current aspect of words as the artist paints the beauty of the fading flowers.

Undoubtedly the meteorologist will continue to define "chinook" and "foehn" technically as descending warm and dry winds, while the newspapers and the people will continue to use the words with differing meanings according as they reside in Montana, on the Pacific coast, or in central Europe, very much as has been done with those unhappy words "tornado" and "cyclone." Hereafter one must be careful to state whether he means a "wet chinook" or a "dry chinook."

But, worse than this! The opening paragraph of our quotation shows that we shall have to write a wholly new meteorology for the school children on the Pacific coast. It would seem that they are taught to believe "that the equatorial trade wind blows during the winter months from the southwest, laden with moisture." The standard trade wind of the English language is not an equatorial wind at all. Every English navigator from before the days of Dampier has told us about the equatorial calms or doldrums, but no one ever yet met an equatorial trade wind lying around loose on the ocean in latitude 40° north. It is really preposterous.—*C. A.*

REFORM IN METEOROLOGICAL METHODS.

In a letter, dated June 3, 1909, Professor McAdie makes the following comments on Prof. W. Koeppen's suggestion that atmospheric pressures be expressed in standard units of force referred to a new normal level:

> The mean altitude of the German weather stations is 107 meters, excluding mountain stations for which the barometer readings are not corrected for height. It would be the same for Europe on the average and for the eastern half of North America. It would not, however, be of any special value for the stations west of the 100th meridian in the United States and Canada; and it may be remarked in passing that this is just the section for which it is of the utmost importance for accurate forecast work in America, that true temperature and reduction factors be obtained. Koeppen points out that—
> "the new normal level would lie in the atmosphere and the calculated pressure have a real meaning; while at present the reduction level * * * lies in the ground where the air pressure denotes only a numerical value, and also the temperature used in the calculation has no reality."
> This is undoubtedly a good point and Doctor Koeppen voices the feeling of all who are actively engaged in forecasting, that there is a need of eliminating the large temperature variation at the earth's surface, in reducing air pressure to a common plane of reference. Many of the "low" and "high" pressure areas marked upon the daily weather charts would disappear, or be greatly modified in outline if the accidental ground temperature values used in reductions were replaced by temperatures more truly representing the conditions in free air.

This is precisely the train of thought followed by me in 1871 and which led to the prompt abolition of the method of reduction then being used for our high stations, namely, above 4,000 feet. An annual constant was adopted for each station which was equivalent, as then stated, to the idea that the use of temperatures varying with each hour of the day was misleading and that at present no reduction whatever should be attempted for these stations. In 1881 monthly constants replaced these annuals by order of a board of officials. The most rational method is that which I recommended to General William B. Hazen as Chief Signal Officer and by him communicated to the International Meteorological Committee at Paris. This was based on the well established fact that the temperature of the free air at any considerable altitude does not change rapidly from hour to hour, hence that the proper temperature to assume and to attribute to the air at any given altitude is the average daily temperature observed at the mountain station or plateau station at that altitude. There are various ways of approximating to this daily average. The simplest way consists in taking the average of the observed maximum and minimum or the average of the current and the next preceding observation with some additional correction for the diurnal variation. Apparently some such idea as this must pervade every good method.—*C. A.*

NORTHERS OF THE SACRAMENTO VALLEY.

By THOMAS A. BLAIR, Assistant Observer. Dated Sacramento, Cal., April 20, 1909.

The northers of the Sacramento Valley form one of the well-marked characteristics of its climate, as distinctive as the foehn winds of the Alpine valleys, or the chinooks of the eastern slope of the Rocky Mountains, to which winds, indeed, these northers are closely related. They occur at intervals throughout the year, attain an average velocity of from 20 to 30 miles an hour, and blow steadily from the north or northwest, accompanied by a very low humidity and, except in the winter months, by a marked rise in temperature. They result from the development of areas of high barometer over the north Pacific coast, and owe their warmth and dryness to the adiabatic cooling and heating which they undergo in their passage over the Siskiyou Mountains. For, in ascending the northern slope of these mountains, which rise to elevations of from 5,000 to 7,000 feet, the air loses much of its moisture; and precipitation occurs with northerly winds on the northern slopes of the Siskiyous, while south of the mountains are the cloudless skies and the dry heat of the California norther.

The exceeding dryness of these northers is their most noteworthy characteristic. On June 17, 1907, at the regular evening observation a relative humidity of 9 per cent was observed at this station, and percentages below 20 are not at all uncommon. In general also, these winds, though northerly, are noticeably warm; but during the winter months their temperature is slightly below the normal, for, coming from regions whose winter temperatures are much below those of the Sacramento Valley, though losing much of their vapor, they are still insufficiently warmed to raise our temperatures. In October, 1906, there were ten consecutive days of prevailing northerly winds, during which there was an unbroken period of 147 hours of north or northwest winds. Three of these days showed in a marked degree the characteristics of the norther. On these days the maximum wind velocities were 31, 33, and 28 miles per hour, respectively; the relative humidities at the afternoon observations, 21, 17, and 20 per cent; and the departures from the normal temperature, −4°, −5°, and −3°. A typical summer norther occurred on June 27 and 28, 1908, on which days the maximum winds were 22 and 15 miles per hour, respectively; the relative humidities, 15 and 19 per cent; and the temperature departures +7° and +10°.

In constructing the accompanying tables, the following conditions were taken as defining a norther: A maximum velocity of 15 miles per hour or more, accompanied by a relative humidity of 40 per cent or lower, during the period from October to March, inclusive, or of 30 per cent or lower, from April to September, inclusive. The tables cover the period from 1902 to 1908, inclusive, being the only years for which we have a complete record of wind directions.

Table 1 shows the number of northers and the duration of each, e. g., March, 1902, had one norther of two days' duration and one of four days. It will be noticed that there were 305 days of northers in the seven years, making an average of 43.6 days a year, or 3.6 days a month. Table 2 is taken from Table 1 to indicate more readily the number of northers and their distribution throughout the year. It is evident that they occur with greatest frequency during the spring and fall

months, and are rare in December, January, and February, and in July and August. A considerable variation in the yearly number is also apparent, the extremes being 14 in 1902 and 21 in 1908. Dividing the total duration, 305 days, by the total number, 118, gives the average duration 2.6 days. It is the popular impression that these winds always last 3 days; but, though the average length just found might tend to confirm this belief, the records in detail show its inaccuracy. For instance, in Table 1 we find 25 northers lasting only 1 day, 40 of 2 days' duration, 27 of 3 days', 17 of 4 days', and 9 of more than 4 days'. Table 3 gives for each month the maximum wind velocity and direction occurring during the prevalence of a norther. The highest velocity during this period was 45 miles from the northwest in May, 1902, Though known as "northers" these winds are more frequently and characteristically from the northwest.

TABLE 1.—*Duration of northers (in days).*

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual duration.
1902...	2	0	2,4	1,3	3	4,2	0	1	3,2,4	1	1	0	33
1903...	0	4,3	2	3,3,2	4,4,2	3,1	3,1	1	3,2	2	0	0	44
1904...	3	0	3	5,2	{2,4,1, 5,2}	{3,2,3	1	2	4	4	0	0	46
1905...	0	1	2,3	2,1	1,1,3	0	6	0	2,2	5,1,2,2	4,2	4,3	47
1906...	1	0	2	5	1	3,3	0	0	2,2	5,1,10	4,3,2,2	0	46
1907...	0	2	2	4,1	2,1,5	4	0	2	1	4	5,2,2,1	0	38
1908...	0	2	3,2,3	{3,3,1, 1,2}	2,4, 2,3	{1,2,3	0	3	4	2,3,2	0	0	51
Duration.	6	12	28	42	52	34	11	9	32	44	28	7	305

TABLE 2.—*Number of northers.*

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1902...	1	0	2	2	1	2	0	1	3	1	1	0	14
1903...	0	2	1	3	3	2	2	1	3	1	0	0	18
1904...	1	0	1	2	5	3	1	1	1	1	0	0	16
1905...	0	1	2	2	3	0	1	0	2	4	2	2	19
1906...	1	0	1	1	1	2	0	0	2	3	4	0	15
1907...	0	1	1	2	3	1	0	1	1	1	4	0	15
1908...	0	1	3	5	4	3	0	1	1	3	0	0	21
Sums..	3	5	11	17	20	13	4	5	13	14	11	2	118

TABLE 3.—*Maximum wind velocity and direction of northers.*

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
1902.	33 n.	0	28 nw.	23 nw.	45 nw.	28 nw.	0	18 nw.	32 nw.	24 nw.	15 nw.	0	45 nw.
1903.	0	40 nw.	15 nw.	35 nw.	40 nw.	15 nw.	40 nw.	15 nw.	40 nw.	24 n.	0	0	40 nw.
1904.	18 n.	0	15 nw.	22 nw.	36 nw.	30 nw.	15 nw.	15 nw.	16 nw.	24 nw.	0	0	36 nw.
1905.	0	16 n.	20 nw.	30 nw.	36 nw.	0	15 nw.	0	20 nw.	38 nw.	40 n.	27 nw.	38 nw.
1906.	29 nw.	0	16 n.	35 nw.	15 nw.	16 nw.	0	0	22 nw.	33 nw.	36 n.	0	36 n.
1907.	0	20 nw.	15 nw.	31 nw.	25 nw.	16 nw.	0	19 nw.	15 nw.	29 nw.	28 nw.	0	31 nw.
1908.	0	26 nw.	33 nw.	36 nw.	29 nw.	22 nw.	0	28 nw.	24 nw.	34 nw.	0	0	36 nw.

The desiccating effect of these winds on soil and vegetation is marked; the soil quickly bakes and cracks, vegetation refuses to grow, lawns and alfalfa fields droop and wilt. Disagreeable and depressing effects are felt by man also; the skin becomes dry, sensitive persons have headaches, and all are cross and irritable. It is said that in the early days of rough and ready justice in California, if murder or violence resulted from a quarrel occurring during a norther, the fact that the north wind was blowing was taken into consideration as an extenuating circumstance! The air at these times is always said to be "full of electricity," and, as was suggested by the investigations made in connection with the foehn, the excess of positive electrons in the lower air may account for some of the disagreeable physical effects of these northers.

These dry and descending winds, cool at night and hot by day, were observed in 1871 and 1872, and in fact occurring as predicted in the early California forecasts. The explanation then given agreed with that of Mr. Thomas A. Blair, adding only that the high area did not always appear first over the north Pacific coast, but more often formed over the mountains of Oregon and Canada and moved southward, spreading westerly a little but mostly to the eastward. Several of the great areas of high pressure studied by Prof. Thomas Russell showed this overflow westward down into the valleys of the San Joaquin and Sacramento. The table given by Mr. Blair is exceedingly instructive and opportune.—*C. A.*

THE FORCE OF GRAVITY AT THE EARTH'S SURFACE.

We have often called attention to the importance of properly appreciating the influence on the atmosphere of any variations in the force of gravity. The subject is now almost definitely set at rest by the researches of Prof. Dr. O. Hecker, of the Prussian Geodetic Institute. In his memoir of 1908 Doctor Hecker states that the most important result of his latest measurements on the ocean is—

That the force of gravity is normal over the Indian as well as over the Pacific Ocean and corresponds to the gravitation formula published by Helmert in 1901. Therefore, for both of these oceans, as well as for the Atlantic, Pratt's hypothesis as to the isostatic location of the masses that form the earth's crust is proven to be correct, so that we can now call it a general law, except for local anomalies. Hence, it can be considered as proven that the smaller density of the water of the ocean is compensated by the greater density of the crust forming the ocean bed. Inversely the continental masses, rising above the surface of the ocean, are not true accumulations of masses upon the earth's crust, but the apparent excessive mass is compensated by a deficiency of mass below the continents.—*C. A.*

METEOROLOGY AT HARVARD COLLEGE OBSERVATORY.

The Astronomical Observatory at Harvard College has carried out several special researches bearing on meteorology in addition to the extensive meteorological work which it has conducted in South America. Especially are we indebted to it for studies into the transparency of the atmosphere from an astronomical point of view. In its Annals, Vol. LXI, part 1, Cambridge, 1908, Prof. W. H. Pickering (the brother of the Director, Prof. E. C. Pickering) summarizes the work recently done by the Boyden department, the expenses of which are defrayed from the fund left by Mr. Boyden.

The late Uriah A. Boyden left $230,000 in trust to aid in the establishment and maintenance of an astronomical observatory on some mountain peak so as to be as free as possible from atmospheric influences. In the search for favorable localities Mr. Pickering says:

It is well known that the deserts of the world lie in two bands, one on either side of the Torrid Zone. They extend in general between 20° and 35° north and south latitudes. These bands nearly coincide also with the regions of calm and of high barometer. As might be inferred from these facts they are also the regions of greatest freedom from cloud. The earth, indeed, according to Leon T. de Bort, (Annales du Bureau Central Météorologique de France, 1884,) as seen from without, must present the appearance of a belted planet, although not so markedly so as Jupiter. The terrestrial belts, however, have this peculiarity, that they move north and south with the sun, but are always a little behind it. Accordingly in tropical countries the rains do not begin until after the sun has crossed the latitude of the place, after which they last for several weeks. Also, as we leave the equator the two rainy seasons approach one another, coinciding near the Tropics.

If we divide the Torrid Zone into two parts, north and south, making with the temperate zones four in all, we shall find that the cloud conditions in these regions show a tendency to alternate throughout the year. Thus, in January the North Torrid and South Temperate zones are clear and the alternate zones are cloudy, while in July the reverse conditions prevail. Since, in the temperate regions, it is clear in summer and cloudy in winter, the presence or absence of the sun accentuates the difference in temperature between these seasons, while in the Tropics the reverse is the case. This furnishes an additional reason why the temperate zones possess such an intemperate climate, while in the Tropics more equable conditions prevail. Thus, at Vercholansk, Siberia, latitude 66° 42′, on the northern boundary of the North Temperate Zone, the temperature ranges from the lowest recorded air temperature at the surface of the earth, −81° F. to +96° F. The highest known air temperature, +130° F., was recorded at Murzuk, Fezzan, in the North Temperate Zone, latitude 25° 49′. Total range of temperature between the two places, 211° F. Both towns are located near the sea level.

The cloudiest part of the world, of which we have accurate knowledge, is the town of Iliuliuk in the Aleutian Islands, latitude +54°, where the observed cloudiness is 82 per cent. The clearest part of the world is Suez, latitude +30°, where the cloudiness is but 6 per cent. The clearest place in the Southern Hemisphere is Omaruru, latitude −22°, on the west coast of Africa, where the observed cloudiness is 11 per cent. The clearest place in the Western Hemisphere is Yuma, Ariz., latitude +33°, cloudiness 17 per cent.

The second of the four atmospheric conditions, the transparency of the air, is met more completely in tropical regions, where hazy skies are almost unknown, than in any of the higher latitudes. The fourth condition, freedom from dew, necessarily implies a dry climate, such as would be found in a desert region.

Especial attention has been given to the optical steadiness of the air. Modern astronomical research demands that observations shall be made when and where the seeing is practically perfect. In many parts of the globe this condition is almost never fulfiled, and in other portions only rarely. Expeditions to determine this feature in the condition of the atmosphere, were made to Colorado in 1887 when the summit of Pikes Peak was occupied as well as many other stations. The old Signal Service records for the station at the summit were published in full. It was found that altitude was not the most important factor. In 1888 an expedition was sent to California and the search for a good station included Mount Wilson. The next expedition was sent to Arequipa, Peru, in 1890–91.

The results of all these expeditions are given in detail in the volume above referred to. It was found that variations in pressure and currents of air are not so important as the slight changes in temperature. Calm nights are better at the tops of mountains than in the valleys.

In 1899 an expedition was sent to the West Indies where the summit of Blue Mountain Peak, Jamaica, was occupied; but the formation of dew on the lenses caused great trouble.

Twinkling of the stars only occurs when atmospheric waves are large in proportion to the diameter of the objective, and was several times noted with the 5-inch telescopes in Jamaica. Good seeing and bad seeing alternate during the night and may depend upon warm and cool currents brought by the wind. The poorest seeing occurred when a hurricane center was aboue 450 miles east of Jamaica.

A slight haze improves the seeing. A dry climate has certain advantages in avoiding dew. A low latitude is better than a high latitude. A considerable elevation is better than a small elevation.

Extensive observations were made of the brightness of the sky at different altitudes in Colorado. The diminution of the diffused sunshine amounts to about one-half for an ascent of 14,000 feet.—*C. A.*

METEOROLOGY AS A STUDY FOR PRACTICAL MEN.

In an address on "What the United States has to Learn from the Educational Institutions and Technical Training of Germany" President Hadley of Yale University said: * * * The children are forced to go to elementary schools for a time, and during that part of their education they are kept out of the shops and factories. They, however, receive instruction in the rudiments of the shop and factory work. They then enter the high schools, going to the "Gymnasiums" for their classical training and to the "Realschule" for the technical instruction. They are graduated as high school students when they finish what would be considered equivalent to freshman studies in a college in this country in so far as the breadth of knowledge is concerned. * * * Following this course, the German young men enter the universities and take up graduate courses in law and medicine or go to the technical schools for their training in civil engineering and other technical courses.

Doctor Hadley laid particular stress upon the growth and usefulness of the technical schools in Germany during the last half century. "Before the spread of these schools in Germany," he said, "the Germans were considered an idealistic and sentimental people. To-day they are intensely practical. They are, indeed, more practical than the Americans."

Our good technical schools are rare. The graduates of our technical schools get most of their training in the shop, on the farm, or in the mine. In Germany the best part of the student's training is received in the schools. The objects of the system in the German schools are two—to develop the individual, and to advance the the welfare of the country by teaching students what will best advance the interests of the country.

The attitude of the public mind in Germany and America toward the respective educational systems is significant. In this country it is regarded as an accident if a man who has been taught the theories of commercial life in the schools succeeds when he begins his active career. In Germany it is considered an accident if success comes to those men who have not been trained in the schools, and an accident that should not be repeated. * * * If such methods succeed in commerce they will succeed in all things. Individual action can not contend successfully with the united front of the Germans in the long run.

I believe there is developing in this country the spirit of organization. There has been a tendency to crowd the technical man out. We are beginning to profit from the lessons of the German educational system, giving our men good training in all lines adapted to practical life.

May we not take up these last words of President Hadley, as printed in the New York Times, November 11, 1908, and urge that meteorology and climatology, with all their applications are eminently practical branches of knowledge, as much so as engineering or astronomy and eminently worthy of being introduced into college and university curricula.

To read the daily weather map correctly and to thus make an intelligent forecast should be an acquirement taught everybody and denied to none. Life and success often depend on this one little art attainable in a six months college course.—*C. A.*

THE RELATION OF THE MOVEMENTS OF THE HIGH CLOUDS TO CYCLONES IN THE WEST INDIES.

By JOHN F. QUINN. Dated St. Croix, Danish W. I., March 18, 1909.

In an article published in the MONTHLY WEATHER REVIEW for May, 1907, the present writer tried to show that, as far at least as concerns the Danish West Indian Islands, the relation of the movements of the high clouds to cyclones is as follows:

The high clouds here, which normally come from a westerly point, go round during the passage of a cyclone, even if the cyclone should be passing at a great distance, to some point in the eastern semicircle, the extent of the deviation from the normal depending on the distance and direction of the cyclone center, the movements of such center governing the movements of the high clouds.

Reference was made in the article[1] to the theory of Father Viñes, that while the lowest air currents in a cyclone tend inward toward the center, the higher currents are divergent and become increasingly so as we ascend, until at the level of the cirrus clouds they move in a "completely divergent radial direction." It was pointed out that Father Viñes maintained that this was the case irrespective of the distance of the cyclone's center, being true even for so great a distance as 550 miles, as he had observed in the case of a cyclone whose center was at that distance east-southeast of Habana, while the the high clouds passing over the city were moving from the same point. Hence, Father Viñes argued that the direction of the cirrus clouds is a direct indication of the position of the vortex of the cyclone.

By comparing observations of high cloud movements here in St. Croix with the charted movements of certain cyclones

[1] Monthly Weather Review, May, 1907, 35:215–18.

in 1905 and 1906, it was shown in the article referred to that the above theory only holds good for comparatively short distances, and that, as the cyclone center moves away, the radiant point of the high clouds shifts farther and farther to the right of the position of the cyclone's center, so that its direction may at last come to be nearly at right angles to the direction of the center.

A quotation from Father Viñes's paper, showed that he himself had recognized this departure from his theory, remarking: "Sometimes, however, the movements of cirrus clouds present great irregularities; thus, for example, when the vortex lies to the northwest or north-northwest in the Gulf States, the current of the cirrus clouds is apt to suddenly come from the northeast." From the present writer's observations it appears that the supposed irregularity is in fact, quite regular; and the *sudden* character of the change depended perhaps on the intervals of time between the observations rather than on the actual course of events. Father Viñes, however, believed that in such cases "the current observed is a resultant of the superior current of the cyclone acting together with the superior general current which at that time of the year comes from the eastern quarter." But this explanation is set aside by the fact that there does not appear to be any evidence for a general upper current from an eastern quarter during the hurricane months. Mr. Page's analysis[2] of 645 observations of high cloud directions at Habana during the hurricane months gave 23 per cent from northeast, 8 per cent from southeast, 39 per cent from southwest, and 30 per cent from northwest; hence, there were 69 per cent from westerly points against 31 per cent from easterly points. Since less than one-third of the movements were from an easterly point, these observations obviously set aside the theory of a prevalent upper current from the east during the hurricane months.

Partly to supplement the article of May, 1907, and partly to adduce further facts furnished by the experience of the hurricane season of that year, the present writer contributed a second article[3] on the cyclone-cirrus relation, which was published in the MONTHLY WEATHER REVIEW for November, 1907.

The purport of the present article is to continue the subject by giving for 1908, the facts bearing upon it so far as they have come within the reach of the writer.

Although it does not appear that any of the islands of the West Indies, except the Bahamas, suffered any very serious damage, the hurricane season of 1908 was a stormy one, and, as will be seen from Table 1, there were no less than twelve occasions when the radiant point of the high clouds, as observed in the Danish West Indian island of St. Croix, passed out of the western into the eastern semicircle, indicating perhaps the passage of an equal number of cyclones, near or remote.

Already in June a deviation of this sort had occurred, and it may be of some interest to consider this case before proceeding to discuss those which occurred in the months usually reckoned as hurricane months, and which are therefore included in the table. An account of this deviation or "excursion" was given in the local paper, The St. Croix Avis, of June 13, and was, in substance, as follows:

From a theoretical point of view the most interesting thing about the weather of the month so far has been one of those remarkable changes in the movements of the high clouds which our editor has sometimes called "excursions." As a rule the high clouds move from the west or neighboring points, but in the hurricane season this direction occasionally swings round, either through south or through north to northeast or east. The swing generally takes several days and seems, in some cases at all events, to mean the passage of a cyclone northward over the ocean, either to the east or to the west of these Danish islands. We are not yet in the hurricane season, nevertheless there has been one of these "excursions," as follows:

Date.	High clouds from:
Wednesday, June 3	WNW.
Thursday, June 4	NNW.
Friday, June 5	*NNE.*
Friday, June 5, 5 p. m.	*NE.*
Saturday, June 6	*NE.* by *N.*
Sunday, June 7	*NNE.*
Monday, June 8	NNW.

From which it will be seen that on the 5th, 6th, and 7th the high clouds were moving from a northeasterly point. What does that mean? In the hurricane season we should say that a disturbance, originating in the Caribbean Sea, far to the west of us, had passed north and was probably felt on the dates just mentioned as a serious storm on the Atlantic to the north of us. Did it mean the same this time, or was there some other cause for the little "excursion?"

To the last question it can not be said that any fully satisfactory answer was later obtained; but in the weekly edition of the London Times, July 24, 1908, a paragraph appeared which was of special interest in this connection. It was a communication from the insurance correspondent of the paper, and reads thus:

The report of the court held in New York to inquire into the abandonment last month of the British steamer *Caribbee* has just been issued in London by the Board of Trade. The *Caribbee* left Mazatlan on June 5 for New York with a cargo of molasses in bulk, and on June 7 a strong gale with a tremendous sea was experienced. In the evening of that day water was found to be rising in the stokehold, * * * and on the following day * * * she was abandoned in latitude 31° N. and longitude 78° W.

Of course the above record can not be held to prove that the *Caribbee* foundered in a cyclone, yet it is interesting to find that a serious storm was blowing off the coast of Georgia while the high clouds in St. Croix were coming from about northeast or north-northeast. A connection between the two facts is at all events probable from what we find in other and clearer cases.

In drawing up Table 1 it has been thought best to divide the circle into eight parts,[4] since this gives a more detailed view of the movements than does a division into quadrants. As a rule one observation has been entered for each day when cirrus clouds were seen by the observer, and slight changes in direction during the day have been passed over. Where, however, considerable changes have occurred in the course of the day these are noted.

It will be seen that twelve "deviations" or "excursions" are noted during the four hurricane months, three in each month, the last deviation extending, however, into November, as far as the 10th, since which date no such deviations have been observed (down to March 18, 1909).

In comparing the high cloud movements with cyclone movements, so far as they are known to the writer, we may commence with the three deviations noted in July. According to the theory, No. I should mean a low originating to windward of the West Indies and moving off to northwest; while No. II should mean a low to the northwest, originating in or to the north of the Caribbean Sea. No confirmatory evidence, however, in regard to these has come to hand, unless the announcement that storm warnings were displayed in the Boston forecast district on the 17th can be claimed as evidence for deviation No. I. In reference to No. III, however, the case is quite different. The cyclonic movement which this deviation appears to represent was first made known to us here in St. Croix on the arrival of the Quebec liner *Guiana*. The steamer had "left New York about midday on Thursday, July 30, and by Friday afternoon, when the ship must have been about 300 miles out, the wind began to blow fresh from south and the sea began to rise. During Saturday (August 1) the wind went round to southwest and blew harder, while the sea increased and the barometer fell from something above 30.00 inches to 29.80 inches. The Weather Bureau had given notice of this storm before the ship left New York, and from the way the

[2] Monthly Weather Review, July, 1904, **32**:311 *a*.
[3] Monthly Weather Review, November, 1907, **35**:510-11.
[4] Lack of space compelled condensing into four quadrants.—*C. A., jr.*

wind changed it appears that the center, which was somewhere between the coast and the steamer, must have passed behind her, moving probably about northeastward." (St. Croix Avis, August 8.)

TABLE 1.—*Movements of high clouds over St. Croix, D. W. I. Hurricane season of 1908.*

Date.	Direction. From a point in the western semicircle. SW. quadrant.	NW. quadrant.	From a point in the eastern semicircle. NE. quadrant.	SE. quadrant.	Excursion number.
1908.					
July 1	wsw.				
July 2		w.			
July 3		w.			
July 7		w.			
July 9	w. by s.				
July 10	sw.				
July 11		w.			
July 13 9:30 a. m				se. by e.	I.
July 13 2 p. m				sse.	I.
July 14 8 a. m				se.	I.
July 14 p. m				ese.	I.
July 15 a. m			nne.		
July 15 5 p. m		nw. by w.			
July 16		nw.			
July 17	ssw.				
July 20 12 m			ene.		II.
July 20 6 p. m			ne. by n.		II.
July 21		nw.			
July 22	wsw.				
July 23	wsw.				
July 24		w.			
July 25 a. m			ne. by e.		III.
July 25 6 p. m			ne.		III.
July 26			ene.		III.
July 27			ene.	e.	III.
July 28			ene.		III.
July 30			e. by n.		III.
July 31			ne. by e.		III.
August 2	ssw.				
August 3	s. (?)				
August 4				se.	IV.
August 5				se.	IV.
August 6				ese.	IV.
August 7				e.	IV.
August 8			ene.		
August 9		w.			
August 11		wnw.			
August 12		wnw.			
August 13	sw.				
August 14	sw. by w.				
August 16			ne. (?)		V.
August 17			ne. by n.		V.
August 18		nnw.			
August 22	s.				
August 24 10:30 a. m		w.			
August 24 6 p. m		nw.			
August 26		nw.			
August 27		nw.			
August 29				se.	VI.
August 31 a. m			ene.		VI.
August 31 4:30 p. m		w.			
September 1		nnw.			
September 2		wnw.			
September 3		nw.			
September 4 6–8 a. m		wnw.			
September 4 p. m	sw. (?)				
September 5		w.			
September 6			n.		
September 7		nw.			
September 8 a. m		nw. by w.			
September 8 3 p. m				se.	VII.
September 9, 1 p. m				e.	VII.
September 10, p. m				sse.	VII.
September 11 7 a. m				e.	VII.
September 11 2 p. m			ne.		VIII.
September 12		nnw.			VIII.
September 13, a. m		n. by w.			VIII.
September 14 8 a. m			n.		VIII.
September 14 6 p. m			n. by e.		VIII.
September 15 a. m			nne.		VIII.
September 15 1 p. m			ne.		VIII.
September 16 a. m				e.	VIII.
September 16 1 p. m				se.	VIII.
September 17	ssw.				
September 18	sw. by s.				
September 20	w. by s.				
September 22	w. by s.				
September 24, 6:30 a. m		wnw.			
September 25			e. by n.		
September 28		nw. by w.			IX.
September 29		nw.			IX.
September 30, 5 p. m		n. by w.			IX.
October 1 a. m			n. by e.		IX.
October 1 2 p. m			nne.		IX.
October 2			ne. by n.		IX.
October 3 8 a. m			nne.		IX.
October 3 p. m			ne.		IX.
October 4			e. by n.		IX.
October 5		nnw.			
October 6		nnw.			X.
October 7		nnw.			X.
October 8 12 m			n.		X.
October 8 5 p. m			nne.		X.

TABLE 1.—*Movements of high clouds over St. Croix, D. W. I. Hurricane season of 1908*—Continued.

Date.	Direction. From a point in the western semicircle. SW. quadrant.	NW. quadrant.	From a point in the eastern semicircle. NE. quadrant.	SE. quadrant.	Excursion number.
1908.					
October 9			e. by n.		Y.
October 10, a. m			ene.		Y.
October 11 6 a. m	sw.				
October 11 5 p. m	ssw.				
October 12	s. by w.				
October 13		wnw.			
October 14		wnw.			
October 15		wnw.			
October 16		wnw.			
October 17		wnw.			
October 18	wsw.				
October 20		nw.			XI.
October 21		nnw.			XI.
October 22 8 a. m		nw.			XI.
October 22 5 p. m		nw. by n.			XI.
October 23			n.		XI.
October 24			nne.		XI.
October 25			nne.		XI.
October 26			nne.		XI.
October 31				sse.	XI.
November 1	ssw.				XII.
November 2 7 a. m	sw. by w.				XII.
November 2 2 p. m	wsw.				XII.
November 3		w. by n.			XII.
November 4		nw. by w.			XII.
November 5		wnw.			XII.
November 6		nnw.			XII.
November 7			n. by e.		XII.
November 8			ne. by n.		XII.
November 10			ene.		XII.

The history of the movement was told more completely in the MONTHLY WEATHER REVIEW for July, 1908, where a cyclonic depression is described as off the Florida coast from the 25th to the 29th, and then as moving along the Atlantic coast and

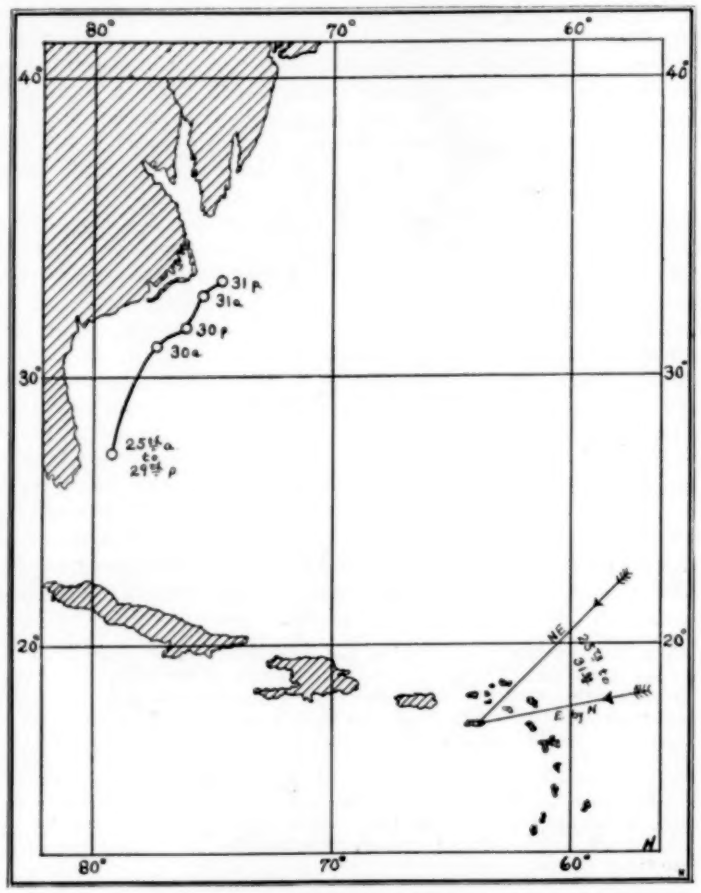

FIG. 1.—Track of cyclone of July 25–31, 1908, and the successive directions of movement of high clouds observed at St. Croix.

was off Cape Hatteras on the 31st with an evening reading of the barometer of 29.32 inches. It is remarked that "the subsequent course of this storm was northeast near the middle Atlantic and New England coasts, and it disappeared over Newfoundland the night of August 2."

The relation between the movement of the cyclone, as given in the MONTHLY WEATHER REVIEW for July, and the movements of the high clouds as observed here is shown in fig. 1.

The first of the August deviations (Table 1, IV), is something like the first in July (No. I), but no information has come to hand which could connect it with a passing cyclone. If such a cyclone existed at all, it was too far away to influence the lower air currents at St. Croix. The barometer at St. Croix rose on the first of the month, then gradually fell a little, the 8 a. m. readings being: July 31, 30.02 inches; August 1, 30.08; 2d, 30.08; 3d, 30.04; 4th, 29.99; 5th, 29.98; 6th, 30.02; 7th, 30.04, and 8th, 30.02 inches. Possibly this was the effect of a distant disturbance, but standing alone it can not be accepted as evidence that there was one.

The short deviations marked Nos. V and VI, should mean distant cyclones, the first toward the northwest and the second toward the north, but no evidence of such has come to hand.

The first deviation in September (No. VII) was simultaneous with the passage of the formidable hurricane that struck Turks Island on September 10, devasted the eastern Bahamas on the 11th, 12th, and 13th, and did much damage to shipping. Its influence on the high clouds passing over St. Croix appears to have been lost on the morning of the 16th, when we learned later the storm center had reached about as far north as the latitude of Bermuda. Already on Monday, September 7, the approach of a cyclone from the Atlantic was predicted at St. Croix by a greater fall of the barometers in the islands to windward than usual between the morning and afternoon readings, as telegraphed to us, and on the following day the high clouds, which were coming very slowly from west-northwest in the forenoon, were seen in the afternoon to have changed their direction and to be coming from southeast.

Attention was called to these facts in the St. Croix Avis of Wednesday, September 9, as follows:

> Some of our readers will have noticed that the barometers at the three island stations from which we get weather news fell on Monday from 10 a. m. to 4 p. m. much more than usual. Instead of the usual 0.05 or 0.06 of an inch, the fall at Barbados was 0.11, at Dominica 0.13, and at Antigua 0.11 of an inch. This suggested the approach of a disturbance from the Atlantic, especially as the barometer fell a little here also yesterday morning.
>
> When the Tuesday morning weather reports came, it appeared that the barometers in all the islands had gone up again as much as could be expected, but in the afternoon they again showed unusual falls: Barbados, 0.09, Dominica 0.11, and Antigua 0.12 of an inch. Note that the fall was greatest toward the north.
>
> What about the high clouds? Yesterday in the early morning they were moving slowly from west-northwest, a motion which during the forenoon slowed down to such an extent that it was only possible to ascertain it with the help of a cloud mirror, but it still continued from west-northwest. About 3 p. m., however, it was discovered that the direction had changed, the high clouds no longer coming from west-northwest, but in a nearly opposite direction; they were moving from southeast. This also points to a cyclonic depression far out on the Atlantic, probably about east of us, and likely to move off toward the northwest.

The cyclone, as was discovered later, was moving fast, and passed to the north of St. Croix during the night of the 9th.

It first made its influence on the lower air distinctly felt here in St. Croix by a strong breeze from northeast late in the afternoon, the weather of the previous part of the day having been cloudy and showery in the morning, but bright in the earlier part of the afternoon. The strong northeast wind went round, during the evening, to north, from which point it was blowing half a gale at 9 p. m. During the night it continued to shift, blowing at 2 a. m., on Thursday the 10th, from about northwest, by 5 a. m. from west-northwest, and by 7 a. m. from southwest. In the writer's weather notes it is stated that the southwest wind was a light breeze which freshened by 8:30 a. m. By noon the cumulus clouds were coming from the south, rather fast, but it is noted that there were "gentle winds during the afternoon, with occasional squalls of rain." Except the heavy sea running on our Long Reef at Christianstad, there was nothing to remind us that a cyclone center had passed us. The barometer in St. Croix (at 8 a. m., unless otherwise stated) stood on the 6th at 30.04, 7th 30.02, 8th 29.97, 9th 29.92, 10th, 2 a. m., 29.82, 4:40 a. m., 29.82, 8 a. m., 29.90, and 11th 30.01 inches.

In St. Thomas the lowest reading of the barometer (aneroid) was given as 29.72 inches, at about 1:30 a. m.

The interesting change in the motion of the high clouds on Tuesday the 8th, from west-northwest in the forenoon to southeast in the afternoon, has already been mentioned. At 1 p. m. the following day the high clouds were coming, as might have been expected, from the east. It is noted, however, that the motion was very slow, from what cause does not appear.

On the following day (10th) the vortex having passed north of St. Croix the high clouds ought, consistently with the theory under discussion, to have come from about northwest or north-northwest, but something quite different happened. In the morning the sky was covered with appressed altocumulus clouds scarcely moving, also at about noon by wind cumulus fast from the south, and in the afternoon in clear blue parts of the sky cirrus, described as fibrous and plumose, was observed coming from south-southeast. After the writer's note of this observation, the query is added: "is there a second cyclone out on the Atlantic?" On the 11th "fine cirrus from east" is noted at 7 a. m., "cirrus from northeast (very slow)" at 2 p. m., and at 9 p. m. it is remarked: "In moonlight, direction of cirrus seemed to be from northeast by north."

The movements on the 10th and 11th seemed so much like a separate "deviation" that they are marked in the table as constituting No. VIII, and the movements which are regarded as connected with No. VII are marked as continuing that deviation from the 12th onwards.

It is known that this storm was raging with destructive force at Turks Island on the night of the 10th and on the 11th, and that it moved slowly northward among the eastern Bahamas on the 12th and 13th, continuing northward over the Atlantic in one of the most frequented lines of traffic. Its disastrous effects are well known.

It is not obvious why the storm should have ceased to influence the high clouds in St. Croix during the 10th and 11th. If, indeed, we knew that a second storm had passed toward the northeast, we might suppose that this was the stronger and had set aside the action of the first storm and replaced it by the movements noted in the table as belonging to deviation No. VIII. But no evidence of such a second storm has reached the present writer.

Whatever may have been the reason of the gap, the great storm appears to have resumed its influence over the high clouds here by the 12th.

Cirrus clouds were on that day noted from early morning. The distant clouds first seen were put down as coming from about northwest; at 11 p. m. cirrus clouds from north-northwest; and at 5 p. m. the following notes were made: "An extensive sheet of cirro-stratus to the west, nearly overhead; greatest length northwest-southeast, moving at moderate rate from north-northwest. On northeast side of the sheet of cirro-stratus numerous beautiful cirrus clouds, curled and fibrous, some plumose, some in rather long streaks crossing each other—an unusually beautiful display—all moving from north-northwest."

From that time the radiant point of the high clouds swung steadily round as the storm center advanced northwest. This

swing is shown in diagram form in fig. 2; but it may perhaps be useful to give here the original notes from which the diagram is framed:

12th. As above.

13th, 8:30 a. m. Sky covered with clouds—most seem to be cirro-stratus in bands lying southeast and northwest—moving at moderate rate from north by west.

14th, 8 a. m. Cirrus in streaks and small irregular clouds—from north, rather fast; 6 p. m., cirrus all day, moving from north by east.

15th, 8 a. m. Fine cirrus—mostly in long streaks, but also some feathers—bars with rounded fronts and other forms, rather fast from north-northeast; 1 p. m., cirrus from northeast.

16th, 8 a. m. Cirrus—a few small and faint clouds in morning, appeared to be moving very slowly from about east.

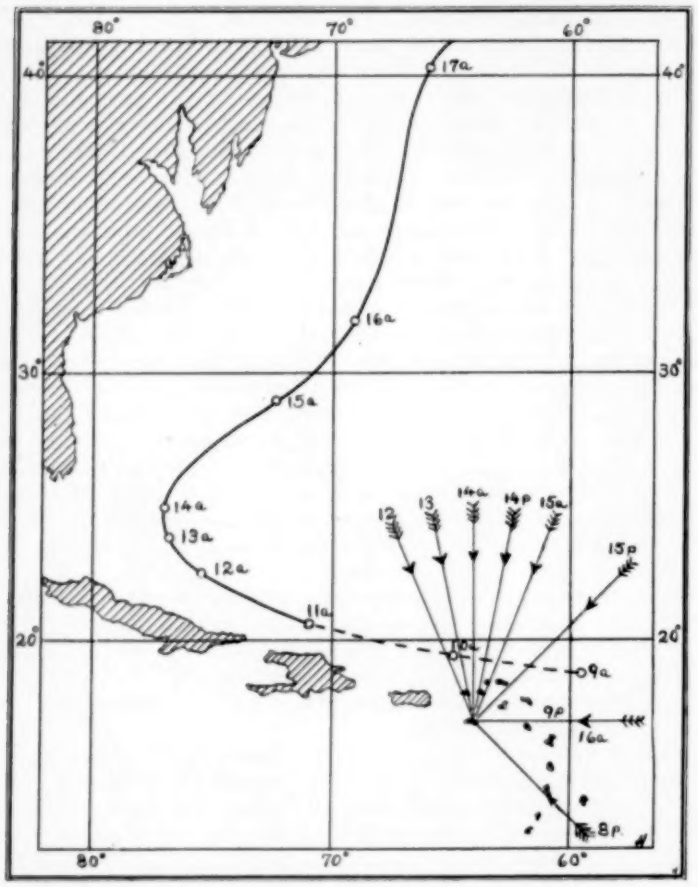

FIG. 2.—Track of cyclone of September 9-17, 1908, and the successive directions of movement of high clouds observed at St. Croix.

In the map of the storm track here given, fig. 2, the larger part of the track (shown by continuous line) has been copied from a chart in the MONTHLY WEATHER REVIEW, the rest is an approximation from local observations, and is marked with a dotted line. On the 10th, in the early morning, the center was about north of St. Croix. For its position on the 9th we are mainly indebted to the courtesy of the captain of the U. S. Revenue Cutter *Itasca*, who sent us, through the lighthouse of St. Thomas, many particulars of the ship's experience in the storm.

The vessel was on her way from Madeira to St. Thomas and first began to feel the storm in the evening of September 8. The wind at midnight was from northeast with a force of 4, the barometer at 29.97 inches. From this time the wind shifted toward east and blew all through the morning of the 9th from east by north, the force rising to 6, 8, and 11. The ship was hove to about 11 a. m., when her position was 19° 42.7′ N., 50° 50′ W., the wind force varying from 8 to 11. At 1 p. m. the wind had changed to east-southeast one-half east, still blowing hard, with heavy driving rain squalls, the barometer 29.85 inches. The weather continued heavy through the afternoon, and afterward gradually improved. From these facts we see that the center of the storm was south of the ship. On the other hand we know from the Antigua reports that it passed north of that island, the wind at 4 p. m. being from north-northwest, the barometer 29.79 inches.

It will be seen from the map, fig. 2, that the swing of this radiant of the high clouds not only corresponded in general with the northward movement of the cyclone center, but increased its rate as the rate of the motion of the center increased.

The direction from east on the morning of the 16th was perhaps in part a movement of the radiant toward its normal westerly position; for, as will be seen from the table, it had gone around to the southeast by 1 p. m. on that date, and by the following morning had reached south-southwest.

We may now turn to the second cyclone (possibly the third) of September (Table 1, Deviation IX). The first intimation of an approaching cyclone received in St. Croix was given, as in the former case, by a fall in the barometers in the islands to windward, which was first noticed on Tuesday, the 22d. The high clouds showed no sign; on the morning of the 24th they were moving slowly from west-northwest, but none was seen later than 9:30 a. m. The night of the 24th was rather stormy, and the morning of the 25th opened with wind blowing hard from northeast and bringing many cumulus clouds with it. The sky was, however, at first sufficiently clear to show an abundance of beautiful cirrus clouds (mostly small forms) moving rather fast from east by north.

This was interesting as confirming the previous evidence that a cyclone was advancing from the Atlantic; but later it became known here that the storm center at that time had just passed over Pointe à Pitre, Guadaloupe, and hence did not lie *east by north* from St. Croix but *east-southeast*, so that the high clouds instead of coming from the storm center, were coming from a position about three points to the left of it.

How are we to account for so considerable a departure from what appears to be the rule?

In answering such a question the possibility of error at one or both ends of the line must not be overlooked. If we first ask what room there is for error at the vortex end, the question is definitely answered by the news from Guadaloupe, which was—that at 1 p. m. on the 25th "a heavy gale started from the northeast, working eastward, total calm suddenly at 5:30, but at 6:15 started from south with increased force till 9:30 a. m." It is quite certain then that the center passed over Guadaloupe in the early morning and no error is possible at that end of the line. Turning now to the other end of the line, it is easy to see that there are at least two sources of possible error, namely, in the observation of the movement itself and in the determination of the character of the observed clouds. In regard to the first of these points the writer can only say that the direction was observed with care, and although no nephoscope was employed the marks used were well known, so that the error under that head, if any existed, could hardly have exceeded a single point. There is more room for error under the second head, namely, the character of the clouds observed. In the writer's notes, made at the time, is this entry: "Partly clear in the early morning; abundant and beautiful cirrus, rather fast from east by north." From memory it may be added that the clouds were mostly rather small and they were white and opaque.

Father Viñes, in the pamphlet before referred to, says on page 11, that "*the light cirrus clouds*, constituting the highest current that falls under our observation, *move as a rule in a completely*

divergent or radial direction, forming with the bearing of the vortex an angle equal to zero or practically inappreciable." (Italics are of the original.) In the paragraph preceding that from which the above quotation is made the author had stated that "in a well organized cyclone of considerable intensity" a great regularity is generally observed in the currents indicated by the different classes of clouds. "In such cases they are apt to form with the bearing of the vortex, angles approximately of six points for the high cumulus, four points for the cirro-stratus, and two points for the cirro-cumulus."

Had the cirrus clouds in the case under discussion presented any resemblance to cirro-cumulus or cirro-stratus clouds, it might be supposed that the explanation of their departure from the general rule would be found in that fact, according to the views of Father Viñes just quoted; but although not "*light*" they seem to have been genuine cirrus clouds; hence it does not appear likely that the discrepancy in question has arisen from an error or errors in the observation.

Possibly an explanation may be found in the undeveloped character of the Guadaloupe storm, for when we read in the news from Pointe à Pitre, "No great damage in town," although the center passed over it, we see at once that the storm at that time was not one of the heaviest. Yet, when "the country districts suffered heavily, large numbers of trees were uprooted, many sugar factories unroofed and cane severely damaged," we perceive that it was not exactly a mild cyclonic movement either.

Whatever may have been the cause of the departure from the supposed rule, its occurrence lessens the value of high cloud movements over these West Indian Islands as a warning signal, while it seems they can only be trusted to give in a general sense, and not as indicators of, the true position of the storm center.

After leaving Guadaloupe the center passed south of Montserrat, where the cotton crop was damaged, and near which a schooner was dismasted. Two days later it was off the coast of Santo Domingo, where it appears to have developed great force, as was shown by remarkably high seas running on the western shores of St. Croix on the afternoon of the 27th and morning of the 28th (Sunday and Monday), and on the western shore of Dominica on the afternoon of the 28th and morning of the 29th (Monday and Tuesday). On the latter island small buildings on the wharves were removed and the jetties damaged by the force of the waves.

From the MONTHLY WEATHER REVIEW for September, 1908, we learn that the storm was central near Port au Prince, Haiti, at 6 a. m. on the 28th, with a reported minimum barometer reading at that place of 29.24 inches. In the MONTHLY WEATHER REVIEW for October, 1908, further particulars are given, and a very interesting description is quoted from the Nassau Guardian, from which it appears that the center passed near and to the west of Nassau on the morning of October 1, where, "by 8 a. m., the barometer had fallen to 28.88 inches, while the wind, southeast, had risen to an estimated velocity of 80 miles an hour—estimated, because at 7:45 a. m. the wind-recording instruments at the observatory were blown away." Much damage was done at Nassau. The MONTHLY WEATHER REVIEW says, that "from the western Bahamas the storm recurved to the eastward over the Atlantic," and that "on the 6th a disturbance that was probably a continuation of the Bahamas' hurricane passed near Bermuda, with a reported barometer pressure of 29.22 inches."

Here in St. Croix we learned something of the storm from the following passage in the St. Christopher Advertiser of October 13, 1908:

The steamer *Uller* of the Armstrong Line, from New York with provisions, arrived here on Friday last, the 19th instant. The vessel received such a buffetting that she was two days late. In fact Captain Olsen reports that he had a terrible voyage. The *Uller* sailed from New York at noon on Wednesday, September 30, and fair weather prevailed until Saturday, October 3, when one of the most terrific storms he has ever experienced was encountered. The storm lasted three days, and at one time great fears were entertained for the ship. The wind and sea were furious.

Although no hour is given for the ship's encountering the storm on Saturday October 3, we may say that, roughly speaking, she had been out three days from New York, and was therefore probably near the thirtieth parallel, and she was in all likelihood heading for the Anegada Channel, so that we can fairly well fix her approximate position. The storm is described as lasting for three days and as causing a delay of two days in the ship's arrival at St. Kitts.

We thought too that we had heard of the same storm when the following telegram reached us on Thursday, October 8:

ST. PIERRE, MIQUELON, *October 8.*

The French fishing vessel *Juanita* foundered in a West Indian hurricane on Wednesday, the captain being the sole survivor out of a crew of 26; he has since become a raving maniac.

It now appears, however, from the MONTHLY WEATHER REVIEW that the center probably moved off across the Atlantic, and the storm that sank the *Juanita* was presumably no West Indian hurricane after all.

An attempt has been made, in fig. 3, to combine the information at hand in a sketch of the storm's course, indicating at the same time in diagram form the high cloud movements at St. Croix that apparently corresponded with its progress.

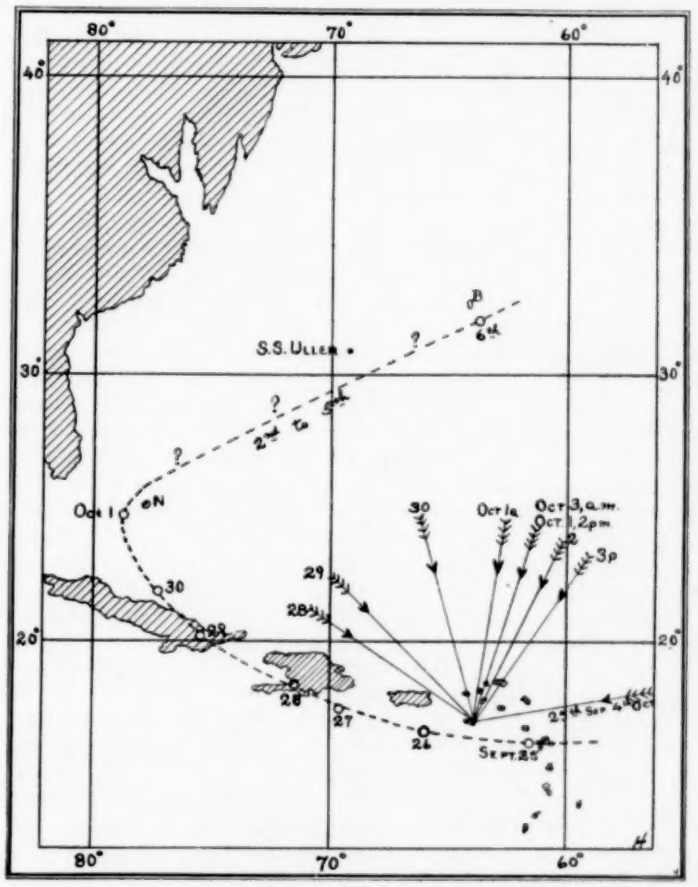

FIG. 3.—Probable track of cyclone of September 25–October 6, 1908, and the successive directions of movement of high clouds observed at St. Croix.

The irregularity on the 25th has already been noticed. There is no obvious reason either for the length of the swing between the 29th and 30th, nor for the retreat of the radiant point from northeast by north on the 2d of the month back to north-northeast on the morning of the 3d.

Possibly a complete map of the storm's course might throw some light on the apparent irregularities, and at all events

the radiant point of the high clouds on the whole moved round with the progress of the storm center.

There remain to be considered the three "deviations" for October which we noted in the table.

The first movement appears to have commenced on the 5th, and the presence of a disturbance around the southern Bahamas and eastern Cuba seems to be indicated by the high clouds moving from north-northwest on the 5th, 6th, and 7th. After which, on the 8th, 9th, and 10th, the radiant point was in the northeast quadrant.

These changes appear to have been the effect of a movement thus referred to in the MONTHLY WEATHER REVIEW for October: "During the 8th a shallow depression that had covered Cuban and Florida waters for several days moved northward over the South Atlantic States."

From the New York Times we learned of the destruction of the custom-house and other buildings, and the wrecking of a schooner at Baracoa, on the northeast coast of Cuba, on the 1st and 2d, and this was possibly connected with the same movement, to which further reference will be made later.

The second deviation (Table 1, No. XI) appears to have commenced on the 18th when the radiant point of the high clouds, which had stood at west-northwest for five days, went around to west-southwest, shifted the next day to northwest and continued gradually around, ending at north-northeast on the 26th.

There is some evidence to connect this movement with a cyclone, namely the local evidence of a very high sea on the south and west shores of St. Croix, commencing on Sunday, the 18th, and continuing on Monday, the 19th. A correspondent at Fredericksted wrote that on Sunday the sea began in the early morning to be very rough, and by 6:30 a. m. the movable parts of the wharf had to be taken up, the waves running almost as high as on the 27th of September. The direction of the waves was from the southwest, and they still continued high on the following afternoon. The lower air here was apparently not affected, and no further evidence of the storm reached us, unless the "low" marked *X* in Chart III in the MONTHLY WEATHER REVIEW for October is the same movement, which is not unlikely. In that case the chart takes it up just where the high-cloud evidence in St. Croix leaves it, namely on October 26.

The third and last "deviation" in October (Table 1, No. XII) appears to have commenced on the last day of the month when the radiating point of the high clouds went around to southeast, whence it continued, through south, to shift with striking regularity till it reached east-northeast, a movement which suggested that it bad gone to the southeast to west, so to speak, a depression entering the Caribbean Sea far to the south, and had then preceded that depression around the circle as it advanced until the control of the cyclone was lost by distance toward the north.

No evidence of a cyclonic movement answering to the above has reached us here in St. Croix, yet the regularity of the changes, as shown in the table, is so striking that it does not seem possible to regard them merely as casual movements. Perhaps later evidence may make clear the meaning of that last great swing of the high clouds as observed at St. Croix in the hurricane season of 1908.

The foregoing paragraphs have been mainly devoted to showing the simple relation which apparently exists between two sets of facts, and very little has been said about the cause of such relation, yet any clear conception of the relation in question must largely depend on our view of its cause. If we think, for example, of a cyclonic depression as sending up from its central portion a great current of air which streams off on all sides (and this is probably true), then we must allow that the high clouds observed by us have proceeded from the center, not in straight lines, but in lines curving more and more to the right as they proceed, and in that case it becomes important to know how long the clouds we see have been on their way. If, for instance, any particular cloud or set of clouds has been twenty-four hours on its way, we must look for its source (the vortex) not in the position it has on that same day, but in the position it had on the day before. If the cloud in question has been twelve hours on its way, then we must look for its origin twelve hours back in the cyclone's track, and so on.

From this point of view, the deviation noted in the table as occurring from the 5th to the 10th of October (No. X) may have some interest.

In the MONTHLY WEATHER REVIEW for October a shallow depression is noted as having covered Cuban and Florida waters for several days prior to the 8th and then to have moved off northward over the South Atlantic States. Figure 4 gives these movements as far as shown in Chart III of the October, 1908, REVIEW, and shows the high cloud movements noted here

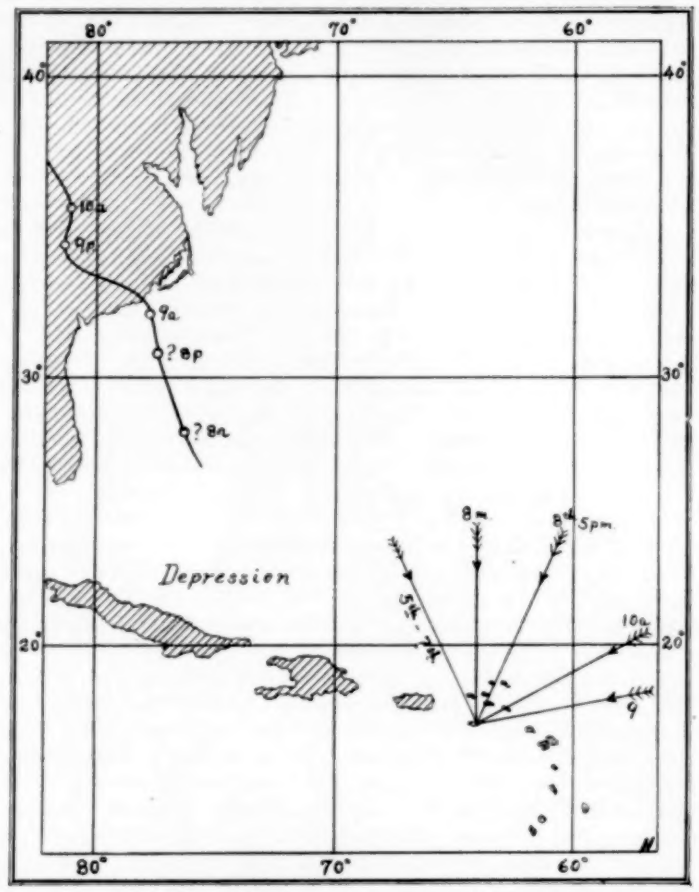

FIG. 4.—Track of a shallow depression of October 8–10, 1908, and the successive directions of movement of high clouds observed at St. Croix.

in St. Croix at the same time. Comparing these, it appears that the position of the center of the depression over Cuban waters may be taken to be represented by the high clouds passing over St. Croix from north-northwest, which lasted for three days; the moving off of the depression toward the north is represented by the shifting of the radiating point to north and thence to easterly points during the next two days. It is true that the high cloud movements do not correspond with those of the cyclone entered on the map, except in the general way above mentioned. The swing from north-northeast on the afternoon of the 8th to east by north on the 9th and then the return to east-northeast on the morning of the 10th should answer to a rapid movement of the depression from its original place in Cuban waters toward northeast and then a return

westward toward the continent to the position on the morning of the 9th. Such a movement is not impossible, but to suppose it to have occurred is to trespass too much on the notes of interrogation that are marked opposite the positions 8*a*. and 8*p*. If we suppose that the high clouds seen in St. Croix down to noon on the 10th moving from east-northeast came from as far away as from the position 9*a*., we assume that they came from about 1,200 miles away, which is perhaps an extreme supposition, yet seems likely when compared with other cases.

A remarkable feature of the above case is that so shallow a depression (at the position 9*a*. the barometer reading is noted as 29.82) should have apparently been able to make its influence over the high clouds felt for so great a distance.

To this it may be answered that the apparent relation between the cyclone and the high clouds is perhaps merely accidental since another depression shown on the same Chart III does not show in the table any corresponding movements of the high clouds at St. Croix. This is true. The depression referred to moved past the west end of Cuba on the 27th, passed over Florida on the 28th, and on the afternoon of that day passed very near the position marked 9*a* of the previous depression (barometer 29.68—therefore, much lower than in the preceding case, yet no effects are shown in St. Croix). Referring to the table, however, we find that *no high clouds at all* were observed at St. Croix on the four days from the 27th to the 30th, consequently it is impossible to say whether the high air was affected or not by the depression then moving along the coasts of the Southern and Eastern States at that time. The writer, turning to his notes for those days, finds on the 27th "No cirrus down to 2 p. m., nor later," and on each of the three following days the words "No cirrus." It was, therefore, not for want of attention that no high clouds were observed on those days. Such gaps, however, are not altogether unknown, even when there is good reason to think that a cyclone is passing, and there must, of course, be a reason, though, as in many other matters touching the weather, it may be hard to find.

Reviewing the last hurricane season's observations of the high cloud movements here in St. Croix we may perhaps say that they seem greatly to strengthen the theory of the cyclone-cirrus relation stated in the writer's former papers on this subject. On the other hand, from a practical point of view, it must be admitted that the failure of the high cloud movements here on the 25th of September to indicate the true position of the center of the approaching storm, and the tardiness of the indications, both in that case and in the first storm of the same month, show that, useful though they may be, we can not rely mainly on such indications, but must still look chiefly to our old guides, the barometer and the movements of the lower air.

METHODS AND APPARATUS FOR THE OBSERVATION AND STUDY OF EVAPORATION.

By C. F. MARVIN, Professor of Meteorology. Dated June 15, 1909.

I.—METHODS.

The splendid campaign of work on evaporation of water from lakes and reservoirs recently undertaken by the Weather Bureau, under the immediate supervision of Prof. Frank H. Bigelow, promises to greatly advance our knowledge of this complex and highly important phenomenon. The essential details of the undertaking and some of the results of preliminary observations have already been more or less fully presented by Professor Bigelow in a number of papers published in the MONTHLY WEATHER REVIEW.[1]

Incidental to the inauguration of the work the writer has been called upon to aid in supplying much of the instrumental equipment required for making the desired observations. It was apparent at the outset that the ordinary markets for scientific apparatus are not prepared to supply any sort of well-designed standard apparatus for the observation of evaporation, and it became a practical necessity to develop and improve upon methods and apparatus previously employed, or to invent new devices of a character easily standardized and manufactured.

In order to reach satisfactory results along these lines it was necessary to carefully examine the whole problem of evaporation in order to learn what sort of apparatus and methods are really essential and to acquire that broad and full understanding of the subject without which the best results are impossible.

The object of the present paper is to give as briefly as is consistent with a clear presentation, what seems to the writer to be the real essence of the matter and to state his conclusions as to methods and apparatus that seem likely to lead to the most useful and accurate results. It is impossible, except in a few cases, to give credit to many other workers before me in this same field, but I am glad to be able to refer the reader who likes to go to the original sources, to the excellent annotated bibliography of evaporation by Mrs. G. J. Livingston.[2]

STATEMENT OF THE PROBLEM.

A great amount of labor and study have already been expended upon the observation and measurement of evaporation by students of agriculture and plant physiology, by engineers, meteorologists, and others, but the results fail to agree, nor can we reconcile the discordances in any satisfactory way. We must, however, recognize that the separate contributions are not necessarily erroneous or inaccurate, but rather that they are solutions of only a part of a large and very complex problem that often has been but imperfectly appreciated and comprehended, and that has not as yet been fully analyzed and solved.

Evaporation, to the engineer interested in great problems of irrigation and the conservation of water supply, means evaporation from large surfaces of water, such as lakes, reservoirs, rivers, ditches, etc. The agriculturist, however, is interested perhaps only in the evaporation from the moistened surface layers of the ground under different conditions of cultivation and treatment, whereas the plant physiologist wants to know about the evaporation from the blades of grass and all sorts of growing vegetation. Another class of engineers wants to know the laws and amounts of evaporation going on under the artificial but none the less definite and important conditions that obtain in drying kilns, curing houses, cooling towers, etc. It seems almost necessary to apologize for emphasizing the fact that each of these constitute a separate and distinct phase of the great general subject, and each requires and must receive separate and special study appropriate to the peculiar conditions. Nevertheless I feel compelled to mention this seemingly obvious fact because I find the problem is often most vaguely and narrowly comprehended even by some who profess to be students of the subject.

We must recognize, therefore, that in the arts and in nature the phenomena of evaporation are going on under a great variety of conditions, so different in fact as to constitute several distinct classes, and that a result, or a form of apparatus that may be entirely sufficient and satisfactory in one class may be of little or no value in another.

In this statement of the general problem it seems necessary to emphasize another seemingly simple and obvious truth, viz, that instrumentally it is a very easy thing to measure evaporation under certain definite and prescribed conditions, but it

[1] See Studies on the evaporation of water from lakes and reservoirs. Monthly Weather Review, July, 1907, February, 1908, Annual Summary, 1908.

[2] Monthly Weather Review, June, September, November, 1908; February, March, April, May, 1909.

is a very difficult thing to correlate the observed evaporation under one condition with that under another. I have been repeatedly urged to invent an instrument to measure evaporation, but in almost every case I have found that the information really desired by the party making the appeal was not how to *measure* evaporation, but how to *correlate* the observed amount under one specific condition with that under another condition.

The evaporation from a cup of water or from a large pan or from a large mass of isolated, damp soil, or from the damp surface of a piece of paper or a porous cup, can each be individually measured with comparative ease and accuracy. When we have these measures, however, we find ourselves confronted by a far more difficult problem, viz: How can we pass from the evaporation observed to take place from a pan to the evaporation from the surface of a large lake or reservoir? How can we find the evaporation from the leaves of plants and growing vegetation, and from the cultivated and uncultivated fields, and from the blanket of snow that covers the ground in winter? And what about the evaporation in kilns, curing houses, dryers, cooling towers, etc? The answers to these several questions can be reached only after having carefully worked out the law of correlation between the evaporation under conditions where it can be measured and which simulate as nearly as may be the conditions under which the evaporation is desired.

The engineer seeking the evaporation from lakes and reservoirs will probably find measurements from pans of water best suited to his needs, whereas the evaporation from moistened disks of paper or porous cups probably best represent the phenomena of transpiration in growing vegetation. Each class of phenomena must be studied on its own merits. The great problem lies in the working out of a correlation; it is not so much a problem of apparatus or of observation.

Thus far we have thought only of evaporation in a given location, where the water supply is actually present. The engineer often desires the answer to yet a different sort of question, viz: "If I build a large reservoir in a given location what will be the loss by evaporation?" This question can not be answered at all at the present time because we do not even know the loss by evaporation from reservoirs already in existence. When this latter has been determined and correlated with the existing meteorological conditions the answer to the other will depend upon what we know of the climatic conditions at the site of the proposed reservoir, and to what extent we can predict how much the building of the reservoir will modify, if at all, the climate of that site and what will be the temperature of the water surface. When the laws of evaporation from existing water surfaces have been satisfactorily formulated it will be a simple matter to estimate, with fair accuracy at least, the evaporation from a proposed reservoir in a climate of known elements.

Having now differentiated the several aspects of the general problem we shall next take up in some detail the question of method and apparatus; but we can not treat the whole subject at this time and we therefore propose to limit ourselves to a consideration of the evaporation from free water surfaces only, such as lakes, reservoirs, etc., having in mind the bearing of this evaporation upon great engineering projects in the interests of irrigation and the control and conservation of water supplies.

CUSTOMARY METHODS AND THEIR FAILINGS.

Engineers seeking to measure the loss of water from a large reservoir or similar body of water have long been accustomed to measure the evaporation from a single pan of water floating in the lake. Sometimes more pans than one have been observed. The pans are not always floated, but sometimes are located on the banks or buried in the soil and otherwise variously exposed. Data obtained in this way do not give us the evaporation from the lake for two different reasons.

(1) The evaporation from the pan is not likely to be the same as the evaporation from the lake, even in the immediate vicinity of the pan, because the temperature of the water in the pan and the effects from other meteorological conditions such as wind, humidity, etc., are quite certain to differ more or less in the two cases. These differences may be small in the case of floating pans, but they are likely to be too large to neglect, especially in the case of pans otherwise exposed. Briefly, therefore, a certain correction or reduction is necessary to enable us to pass from the observed evaporation in a pan to the estimated evaporation from a free water surface in the immediate vicinity.

(2) Even if we can apply this correction to our observation and thus find the evaporation from the lake or reservoir in the given locality, we are not at all justified in assuming that the evaporation is the same over the whole exposed surface. There are many reasons why the evaporation should differ from point to point, especially in arid and semiarid, windy regions, where evaporation is very active. To windward the loss of water is greatest unless high sheltering banks cut off the free access of dry winds, and the amount falls off rapidly as the air moves over the water and itself becomes charged with moisture, thereby lessening the evaporation from the surface over which it subsequently passes.

Integration of evaporation.

The rate of evaporation over a large water surface in dry, windy regions is therefore very unequal and the total loss of water can be ascertained only by some sort of summation or integration of the variable amounts.[3] How this may be worked out is indicated by the graphical method of integration described below.

Let fig. 1 represent an outline or map of the body of water whose evaporation is under study. Suppose the evaporation has been measured at numerous points more or less uniformly distributed over the surface, as, for example, by the aid of

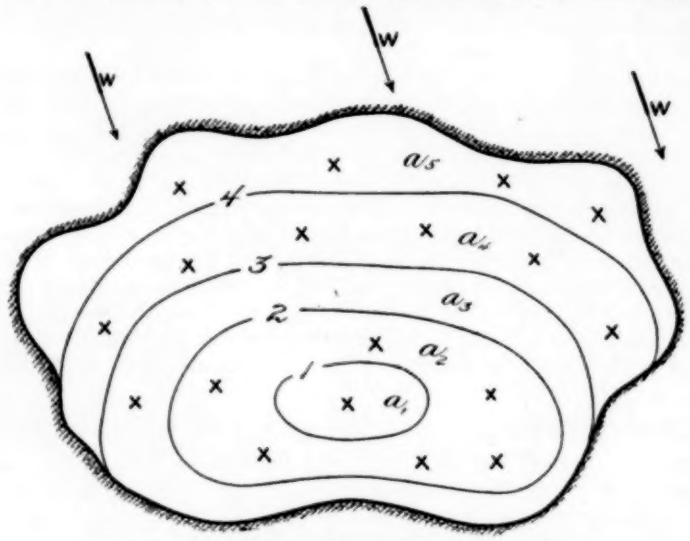

FIG. 1.—Diagramatic integration of evaporation.

floating pans. If the amounts of these evaporations are plotted on the map then we can draw such lines of equal evaporation or "*isothymes*,"[4] as are indicated by 1, 2, 3, etc., in fig. 1. The inter-relation and configuration of these lines will no doubt have a more or less definite relation to the amount and direction of

[3] In a few exceptional cases it may be possible to accurately measure the inflow, outflow, and seepage of a sea or reservoir; then, of course, evaporation = inflow — outflow and seepage.

[4] Mr. C. Fitzhugh Talman has kindly called my attention to the fact that Aristotle has used the word "*thymiasis*" in nearly the same sense as our word evaporation, and it therefore seems that such combinations as "*isothymal*," "*isothymes*," etc., are justified by this ancient usage.

wind movement, the form and extent of the water surface, the topography of the environment, etc. Let the areas between the several "isothymes" be ascertained and designated by a_1, a_2, a_3, etc., and let A = total area of the water surface. Now we may reasonably assume that the average evaporation over the area a_1 is the mean of the observations that fall within that area. For the areas a_2, a_3, etc., it will be sufficient doubtless to take the mean of the "isothymal" lines bounding the respective areas. Let these several average amounts of evaporation be represented by E_1, E_2, etc. It now plainly follows that the total loss from the whole surface is given by the equation

$$E = \frac{a_1E_1+a_2E_2+a_3E_3+ \quad . \quad . \quad . \quad a_nE_n}{A} \quad \ldots\ldots\ldots (1)$$

Obviously this method, with a large number of observations carefully plotted, gives the result sought for with great accuracy. How serious the error may be when only one or a few observations are used, can not be told until the process here indicated has been systematically applied and at least some data obtained to show how much the evaporation differs from place to place over an extended water body under different conditions. This important method of analyzing the problem has not been followed out to any definite result so far as I know. Apparently a systematic study of the amount of variation in evaporation over large surfaces of water subjected to widely different atmospheric surroundings, constitutes a first step to the solution of the problem in hand. No matter how carefully or how accurately the evaporation is measured from a floating pan or one exposed in any other manner, it will never be possible to calculate the loss of water from a large lake until we have definite data upon which we can lay out a map of the distribution of the evaporation over the surface

The evaporation equation.

It is almost futile to strive, as is often done, to so dispose a pan of water by floating it, for example, that its whole environment shall be *identical* with that of the water in a lake. Whether we use a large or small pan, and float it in the water or on a raft, or expose it otherwise, the water temperatures are always more or less different; and do what we may the action of the wind on the free water surface is very different from its effect on the water in the pan, so we are compelled in any case to take account of greater or less differences in environment between the water in the pans where we can measure the evaporation and the water of the body whose evaporation is desired. Now to enable us to take account of these differences we must have an evaporation equation which expresses the influences the surrounding conditions exert on the evaporation and when we have this equation it is then no longer necessary to confine ourselves to some particular kind of evaporation apparatus exposed perhaps in some manner that renders observation and maintenance troublesome, inconvenient, and difficult, but we can, instead, avail ourselves of more simple and convenient apparatus easily observed and maintained.

Various attempts have been made to formulate such an equation as now required, but these differ not only in form, but especially in the value of the several supposed constant terms, so that when they are applied to one and the same case very different amounts of evaporation are indicated. The equations fall sharply into two classes: (1) Those developed from the mathematical and thermodynamic equations representing the phenomena of pure diffusion; (2) partly rational and partly empirical equations that aim to express the relation between the measured evaporation and all the meteorological conditions by which it is influenced.

Evaporation by pure diffusion.—Lord Kelvin[5] applies the general equations of pure diffusion to a large number of practical everyday problems and points out in the case of the diffusion of carbon dioxide through air that the results prove that its approximately uniform distribution is due to convection not to diffusion. The same is true of water vapor. Stefan and others have endeavored to develop equations for evaporation based upon pure diffusion, but the fundamental simple assumptions essential to the mathematical treatment of the problem are highly artificial and do not represent any real conditions that actually arise in nature.

[5] Encyclopedia Britannica, 9th edition. Article, "*Heat.*"

The writer has just completed a very careful series of measurements of evaporation of water from a 50-inch pan filled to the brim, exposed in a large room under conditions that approximate those of pure diffusion from a small source into a very large medium. Such evaporation is very slow. During twenty-three days the average rate was 0.00293 centimeters per hour. The least amount reported by Professor Bigelow at Reno, when the wind was estimated at 1½ to 2 kilometers per hour, was sixteen times greater than that here observed. On several days, with dry weather conditions prevailing outside, the air in the room at a point 2 feet above the pan contained scarcely any more water vapor than the general room air which on these occasions ranged from 35 to 50 per cent relative humidity. These observations were obtained by the use of a special hair hygrometer to be described later. The readings were constantly checked by sling psychrometer readings and are entirely reliable. The moisture contents of the air in the room rose and fell from day to day strictly in accord with the outside weather conditions, and the effects of the evaporation from the pan were scarcely observable, notwithstanding that pains were taken to avoid renewal of the room air by ventilation, etc. The whole evaporation by diffusion, even when aided by some convection and accidental air currents which we know must have existed, did not appreciably modify the moisture conditions of the general room air.

To still further demonstrate the extreme slowness of evaporation by diffusion, another experiment was made. A dish of water, 63 milimeters in diameter, was placed in an air-tight chamber having a capacity of about 1 cubic foot, with a hair hygrometer at the top. The experiment was started when the outside air had a humidity of 43 per cent. At the end of six hours the humidity at the top of the chamber had risen from 43 to 69 per cent. The subsequent rise of humidity was very slow, and saturation was not attained until after eight or nine days. Finally, the same experiment was repeated with a small electric fan running gently inside the chamber. Saturation was reached after 2¼ hours.

The difference between evaporation in still air by diffusion and that which occurs in nature when the air is stirred by even the most gentle zephyrs is very great, especially when the air is relatively dry or of low humidity, and this important fact must be incorporated in the evaporation equation.

The Dalton equation.—The equation which has been used by nearly all those who have made a study of evaporation is due to John Dalton, 1803. In stating the Dalton and other equations the following notation will be employed:

$\frac{dE}{dt}$ = depth of water evaporated in the interval of time dt.

E_1 = depth of water evaporated in one hour.

e = general symbol representing vapor pressure.

e_s = saturation vapor pressure at temperature of the water surface.

e_a = saturation vapor pressure at the temperature of the air near (within a few feet of) the water.

e_d = saturation vapor pressure at the temperature of the dew-point in the air near the water.

$\frac{de}{ds}$ = expression representing the change of vapor pressure with temperature as signified by the term S = temperature of the surface of the water. This quantity is merely the tabular difference in ordinary vapor pressure tables at the temperature under consideration.

τ_a = temperature of the air on the absolute scale.

v = velocity of wind.

B = barometric pressure,

C, a, etc = supposed constant terms.

The Dalton equation may be written as follows:

$$\frac{dE}{dt} = C(e_s - e_d)(1+av) \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Many careful writers on the theory of evaporation, including Dalton, have recognized the influence of air pressure on evaporation, and as early as 1789 Saussure directly compared the evaporation on an elevated mountain pass in the Alps with that under similar conditions at Geneva, where the air pressure was greater in the ratio of nearly 3:2. He found that the evaporation was over twice as great in the Alps. Those who have applied the Dalton equation to practical observations have sometimes ignored the pressure term even where the range of pressures comprised within the data has been considerable.

The following results quoted from Prof. F. H. Bigelow[6] give the evaporation in millimeters per hour for an assumed case of water temperature 23.9° C., dew-point temperature 15.6° C., wind velocity 10 meters per second (35.8 kilometers per hour). The values are computed by the Dalton equation, using the coefficients found by the several authorities cited:

Abbassia (Egypt), $E_1 = 0.1337$ millimeters ... (3)
Fitzgerald (Boston, 1887), $E_1 = 0.2162$ millimeters ... (4)
Carpenter (Fort Collins, 1887), $E_1 = 0.1504$ millimeters ... (5)
Stelling (Russia, 1875, 1882), $E_1 = 0.3495$ millimeters ... (6)

The present writer adds the following values from Bigelow's work at Reno, Nev., and Mecca and Indio, Cal.[7]:

Pan on ground, irrigated alfalfa field, Reno, Nev.,
$E_1 = 0.658$ millimeters ..... (7)
Pan on ground, partly irrigated field, Date Garden, Indio, Cal., $E_1 = 0.476$ millimeters ..... (8)
Pan on ground, Date Garden, Mecca, Cal.,
$E_1 = 0.438$ millimeters ..... (9)
Pan on ground, dry field, Indio, Cal.,
$E_1 = 0.261$ millimeters ..... (10)

The engineer may well be at a loss to choose between this widely discordant data, which testifies to the inexactness of our present knowledge of the subject.

Reno, Nev., is 4,500 feet above sea level, with an average air pressure at about 25.5 inches, whereas Mecca and Indio, Cal., are at or slightly below sea level. This condition may partly explain the seemingly great evaporation at Reno, Nev., but the effect of pressure on evaporation has been omitted by Bigelow in his discussion of these observations.

The Weilenmann equation.—Weilenmann[8] developed an equation with great care, which he proposed be used to compute the monthly and seasonal evaporation directly from the known meteorological elements. While we can not accept the numerical coefficients employed by Weilenmann, the form of equation developed by him is worthy of brief discussion.

Using the notation adopted above, his equation may be written as follows:

$$\frac{dE}{dt} = \frac{C}{\tau_a\left(\frac{de}{ds} + AB\right)}(e_a - e_d)(1 + aBv) \quad \ldots\ldots (11)$$

Although this resembles the Dalton equation (2), yet it presents notable differences. The pressure term B not only comes in with the C term, as has been customary with some writers, but it also modifies the wind coefficient a. The term e_a will be the same as e_s in (2) if we suppose the evaporating water and air have the same temperature. This was not so assumed, however, by Weilenmann. The equation also contains the term τ_a = the absolute temperature of the air and the term $\frac{de}{ds}$, in which latter feature the equation anticipates Professor Bigelow's use of this ratio. For purposes of comparison, we may write here the Bigelow equation, as follows:

$$\frac{dE}{dt} = C.\frac{e_s}{e_d} \cdot \frac{de}{ds} \cdot (1 + av) \quad \ldots\ldots\ldots\ldots (12)$$

Weilenmann explains that $\frac{de}{ds}$ must be taken for a temperature between the air temperature and the wet-bulb temperature and Bigelow takes $\frac{de}{ds}$ for the water surface temperatures. Now water evaporating freely in a pan will take on a temperature which will average below the air temperature but yet be warmer than the wet-bulb, so that this term in the two equations will be nearly the same, except that it stands in the denominator in one case and in the numerator in the other. The latter, i. e., the Bigelow usage, seems to be the more rational.

Marvin equation.—The foregoing appear to be the most noteworthy evaporation equations, but a number of other forms have been proposed. No one of them all will give zero evaporation under those conditions in nature under which we know from physical laws that the evaporation must be zero. Nor will any one of these equations, except the Dalton form give *negative evaporation*, i. e., show condensation which takes place every time the water temperature is less than the dew-point temperature. Negative evaporation was observed experimentally as early as 1750 by Richman and has since been repeatedly recognized by many other writers and doubtless by many observers of evaporation.

The present writer proposes[9] an evaporation equation of the following form:

$$\frac{dE}{dt} = \frac{C}{B}(e_a + e_s - 2e_d) \cdot f(e) f(v) \quad \ldots\ldots\ldots (13)$$

In the absence of sufficiently complete observations of a suitable character it has not been possible to evaluate the constant factors or give the exact form of the terms depending on wind and atmospheric moisture. The new feature of this equation is the expression $(e_a + e_s - 2e_d)$. If we assume that the water and air are at the same temperature, as is nearly the case with the usual evaporation pans, then when this term is large or small, positive, negative, or zero the evaporation must be large or small, positive or negative, or zero. In these respects the equation gives consistent and rational results over the whole range of conditions which occur in nature and this is not equally true of any other equation that has thus far been proposed or used. The expression $(e_a + e_s - 2e_d)$ appears to indicate too much evaporation when the water temperature is considerably lower than the air temperature.

[6] Monthly Weather Review, July, 1907, 35:313.

[7] Monthly Weather Review, Annual Summary, 1908, 36:442-3, computed by using the C_d coefficients from Table 28 for pan 1, tower 4, viz, $C = \frac{1}{3}$ (0.073); Table 29 (wind 10-20), pan 1, viz, $C = \frac{1}{3}$ (0.0528), and $C = \frac{1}{4}$ (0.04860), also Abbe, Table 31, pan 4, viz, $C = \frac{1}{4}$ (0.029); the wind coefficient, = 0.0175.

[8] A. Weilenmann: Die Verdunstung des Wassers. Schweiz. met. Beobacht., 1877, 12:268-368. Reprinted, Zurich, 1877.

[9] C. F. Marvin: A proposed new formula for evaporation. Monthly Weather Review, February, 1909, 37:58, equation (6).

OBSERVATIONS MOST NEEDED.

Two classes of observations are essentially necessary before we can reach a satisfactory answer to the general question, "What is the amount of evaporation from an extended expanse of free water surface?"

I.

In order to establish all the details and evaluate all the numerical coefficients of the general evaporation equation we must have a large number of accurate measurements of evaporation under a wide range of atmospheric conditions, all of which must be carefully determined.

The observations must give us:

(1) The temperature of the water surface.
(2) The temperature of the air within a few feet of the water.
(3) The vapor pressure in the air near the water.
(4) The velocity of the air movement within a few inches of the water.
(5) The atmospheric pressure (within 1 or 2 per cent).
(6) The evaporation.
(7) Rainfall, condensation, etc.

The influence of salinity, impurity of the water, cleanliness of the surface, etc., are all fully recognized, but we hardly need consider these in the present paper.

There are many reasons why the great mass of existing data fails to supply our present needs. For example:

(*a*) Widely different methods and apparatus have been employed, yielding data which can not be definitely correlated.
(*b*) One or more important factors influencing evaporation are often omitted from the observations.
(*c*) Even if not actually omitted, one or more factors are often imperfectly determined.
(*d*) Faulty, irrational, and incomplete mathematical formulas are often employed to express the relations between conditions and effects.

The practice of multiplying *ad infinitum* great masses of data collected by faulty, incomplete, and inexact methods can not be too strongly condemned. Such observations do not reveal, but rather serve to obscure the real facts of nature. Reliance is placed upon elaborate methods of mathematical discussion and the sorely abused theories of probabilities, and it is imagined that grave errors of observation have been eliminated by the mere mass of data digested. It may fairly be said that 100 carefully made observations, each of which represents certain definite physical facts, are worth more than many thousand inexact, loosely related readings in which the errors of observation are mostly of a greater order of magnitude than the differential effects we seek to discover.

These considerations indicate how important it is, *first* to make only the best possible observations, *second* to subject all observational data to searching cross examinatian with a view to showing up its own inconsistencies, errors, etc.

Wind observations.—There are no less than six different and independent variables in the problem of evaporation and in nature practically all of these are wholly beyond our control. It is of the greatest importance, therefore, when collecting observations for a formula that the related data be determined accurately for short intervals of time during which the changes in the conditions may be minimized. This is particularly necessary with respect to the wind which often undergoes great changes in short intervals and in dry regions especially influences the evaporation very greatly. This consideration has led the writer to perfect a special form of apparatus which records simultaneously on the *same* sheet the wind and evaporation, including rainfall, if the evaporation pan is not sheltered against precipitation. This apparatus will be fully described in Part II, of this paper.

The diurnal march of air, water, and dew-point temperatures, as a rule, closely approximate simple harmonic curves, and while automatic records or frequent observations of these elements are of great value they are not so absolutely necessary as in the case of the wind. In dry climates even small changes in light winds produce large changes in the evaporation, whereas considerable changes in strong winds have relatively small differential effects. On the other hand when the atmosphere is already heavily ladened with water vapor both light and strong winds have relatively little influence upon the evaporation.

Rain-sheltered pans.—When rainfall occurs frequently and in considerable amounts it is practically impossible to accurately determine the evaporation if the rain is permitted to fall into the evaporation pan. In the writer's opinion the only plan to follow is to roof over the evaporation pan so that no rain can fall into the apparatus. This roof must not obstruct the perfectly free flow of the wind underneath. A pan so exposed will of course show a different march of temperature conditions, but the evaporation equation which will ultimately be developed will take complete account of this, and there are many very great advantages in the use of rain-sheltered pans. This plan has been recently put in operation by Mr. F. DeS. Willson on the Isthmian Canal Zone. Evaporation often goes on continuously during showers, as the air then is not necessarily saturated.

Treatment of averages of variable conditions.—Weilenmann, Stelling, Bigelow, and others who have attempted to calculate the evaporation for a long interval by using the *average* meteorological conditions for a day, for example, or a week or a month have uniformly disregarded an important mathematical consideration. If the wind, humidity, temperature, etc., remain constantly the same throughout a whole day, for example, we get a certain amount of evaporation. If, however, large changes occur in the conditions throughout the day it is quite certain a different amount of evaporation will result, even though the averages of the variable conditions are the same as the constant conditions. Stelling discovered in his computed results discrepancies exceeding 10 per cent for which he could find no explanation and which were doubtless caused by neglect of the point we are now discussing. Calculations based on averages must deal with the integral, not the arithmetical mean.

Observations on towers, etc.—Measurements from pans at different elevations above the ground and above water surfaces such as are now being made for the Weather Bureau under Professor Bigelow's direction give a number of interesting data, but only a part is useful in solving the great problem of evaporation. If the observations are made simultaneously at the different levels or are so arranged as to eliminate the effects of constantly changing conditions they give us:

(*a*) The vertical gradient of temperature of the air;
(*b*) The vertical gradient of vapor pressure in the air;
(*c*) The vertical gradient of wind velocity;
(*d*) The evaporation from pans of water exposed under these different atmospheric conditions.

The vapor pressure measurements at the different towers and levels may possibly serve to outline the form and indicate the different densities of the so-called vapor blanket that we imagine overlays large water surfaces. This filmy blanket, however, is utterly torn and disintegrated by the ordinary winds which change quickly and greatly, and are constantly intermixing variable amounts of new air and vapor with that of the blanket. It seems that any effort to outline and define this evanescent vapor blanket by means of the small number of observations thus far provided for is not likely to yield a real truth in nature.

The useful material obtained from the tower observations is the evaporation under different winds, temperatures, etc.,

all of which is of great value in establishing the coefficients of the evaporation equation. Observations of this nature can be obtained, however, quite as well by other methods of exposure.

Laboratory experiments.—Our inability to control in any way the several factors that influence evaporation in nature not only makes field investigations difficult and the results uncertain, but suggests the desirability of making such investigations by so-called laboratory methods. Fitzgerald's experiments on the effects of water temperature on evaporation are a notable contribution of this character. The writer is strongly in favor of a vigorous campaign on evaporation by laboratory methods. At the same time the great difficulty of producing and maintaining artificially all the desired conditions on a sufficiently large scale is recognized and constitutes quite as serious an obstacle to ultimate success as the difficulties encountered in field work.

II.

Yet a second class of observations is required in solving the question of evaporation from free water surfaces, viz, those necessary to bring out the laws of distribution of the variable evaporation over any considerable expanse of water. This has been fully explained in connection with fig. 1 and equation (1) above, but so far as known to the writer no systematic study of the problem has been attempted.

In the opinion of the writer, observations from pans floating in the water are almost the only data we can procure from which we may hope to be able to compute the true evaporation from an extended free water surface. The plan of calculating the evaporation from a few observations of temperature, wind, and vapor pressure is certain to prove crude and inaccurate unless the plan is carried out on a far more elaborate basis than is commonly expected. An observation of evaporation is a very definite and exact integration of a very subtile and highly variable phenomena. I think it is decidedly easier, more exact, and more scientific to actually *observe* the integrated result sought after than to try to compute a result from scanty observations upon several other phenomena to which the evaporation is indirectly related. The latter plan is only justified for crude results and when the more exact method is not available.

It has seemed worth while to bring out with some clearness all the general facts and principles presented in the foregoing because separately they will be found abundantly supported by the past literature of evaporation, but collectively they have not all been systematically and consistently regarded by each or any individual worker. No one may hope to formulate the true general laws of evaporation applicable anywhere and everywhere without paying careful regard to the lessons that are taught by the work and mistakes of others.

Section II of this paper will describe instrumental apparatus.

[*To be continued.*]

A CHRONOLOGICAL OUTLINE OF THE HISTORY OF METEOROLOGY IN THE UNITED STATES OF NORTH AMERICA.

[*Continued from the Monthly Weather Review, March, 1909.*]

1851. E. E. Merriam, "The Sage of Brooklyn Heights," began the publication in the New York daily papers of a series of articles on "Heated terms and other weather phenomena." In 1853–1855 he frequently ventured on local weather forecasts, based in part on his own observations in Brooklyn, but largely on the telegraphic reports published daily in the newspapers.

1852. October. Date of Espy's fourth meteorological report, addressed to the Secretary of the Navy; called for by Congress July 24, 1854; referred to the Secretary of the Smithsonian Institution; ordered printed; published in 1857, with numerous notes which brought it up to the date of publication. This fourth report also reprints all of Espy's preceding reports.

1852. First edition of Arnold Guyot's collection of "Meteorological tables for Smithsonian Observers." A second edition appeared in 1857; a third edition in 1859; a fourth, or Libbey's edition, in 1884; a fifth, or Curtis's edition, in 1893; a sixth, or McAdie's edition, in 1896; a seventh, or third revised edition, in 1907.

1853. Meteorological stations established at grammar schools in Canada.

1853. Mr. Joseph Brooks, manager of a line of steamers between Boston and Portland, is said to have used the telegraph freely in obtaining information about the weather as affecting his navigation.

1853. Lieutenant M. F. Maury secures an International Meteorological Conference at Brussels, leading up to cooperation in marine work.

1853. William Ferrel (*b.* 1817, *d.* 1891) published a first popular article on the effect of the rotation of the earth on the winds and the ocean currents.

1853. November. James Henry Coffin (*b.* 1806, *d.* 1873) published his "Winds of the Northern Hemisphere" as a result of many years of work.

1853. Lorin Blodget published "On the Abnormal Atmospheric Movements of the United States," in the Proceedings A. A. A. S., 1853.

1854. Prof. Joseph Henry reported that the telegraph companies were furnishing the Smithsonian Institution with daily morning weather reports. He had suggested the custom, which became established, in accordance with which the first message each morning on opening any telegraph office was in answer to the salutation, "Good morning, what is the weather?" Each local operator gave to his division superintendent and the local newspapers a statement of these weather reports, viz, temperature, wind, and weather, and all of them were telegraphed to the Smithsonian Institution, where they were exhibited on a large wall map day after day during the years 1854–1861. These reports were frequently used by Professor Henry to predict or show the possibility of predicting storms and weather, a matter that he frequently urged on the attention of Congress. Espy and Henry were the prime movers in all matters of storm predictions both in this country and in Europe.

1855–1859. A series of five papers by Joseph Henry on "Meteorology in its Relations to Agriculture," published in the reports of the Commissioner of the Patent Office. They were reprinted (1886) by the Smithsonian Institution as Vol. II of Henry's Scientific Writings.

1856. Lieut. Silas Bent, U. S. N., initiates the Gulf Stream and Japan Current delusion.

1856. Espy invented his double nepheloscope and showed that expansion alone into a vacuum does not produce cloud or cooling since there is no work done by the expansion.

1857. Lorin Blodget (*b.* 1823, *d.* 1901), published his "Climatology of the United States."

1857. October 22–November 17, Espy ordered to transfer his work from the Smithsonian Institution to the U. S. Naval Observatory.

1857. William Barton Rogers (*b.* 1805, *d.* 1882), published in Silliman's Journal, a paper on the breaking up of a steady current of wind into an anticyclone on the right-hand side, and a cyclone on the left-hand side.

1858–1860. William Ferrel, published in the American Mathematical Monthly, a mathematical memoir on the motions of solids and of the atmosphere on the surface of the earth. This was followed eventually by his Meteorological Researches, Part I, 1875; Part II, 1878; and Part III, 1881; and by his joining the meteorological division of the U. S.

Signal Service in 1882; by the publication of his "Recent Advances," (1885), his "Popular Treatise on the Winds," (1889), and other special papers.

1860. Loomis published "On Certain Storms of 1836 in Europe and America."

1865. The Smithsonian Institution published Part I of Meteorological Records of Storms during the years 1854–1859. Part II was published about 1868.

1865. The U. S. Commissioner of Agriculture, Hon. Isaac Newton, indorsed the recommendation of Prof. Joseph Henry that a weather service be established for the benefit of agriculture, more extensive than that which had been maintained hitherto by the Smithsonian Institution in connection with the U. S. Commissioner of Patents.

1868. Dr. B. F. Craig, of the Surgeon General's Office, improved the apparatus and introduced a protected sling-psychrometer at the stations under his control.

Publication of Loomis' Treatise on Meteorology.

Establishment of the New York Meteorological Observatory under the control of the Central Park Commission. Annual volumes of observations have been published and automatic records maintained by the director, Dr. Daniel Draper.

1868. May 1. In an inaugural address as Director of the Cincinnati Observatory, Prof. Cleveland Abbe (*b.* Dec. 3, 1838) proposed the establishment of a weather service and forecasts for the benefit of the citizens of Cincinnati. In July, 1868, the Cincinnati Chamber of Commerce authorized cooperation with the Cincinnati Observatory in this work.

1869. In August of this year the Cincinnati Chamber of Commerce officially invited the Chicago Board of Trade to unite in extending the benefits of its daily weather bulletin to the lake region; the matter was referred by the Chicago Board of Trade to the Chicago Astronomical Observatory, where the offer was declined.

1869. September 1. Telegraphic reports and "Weather Probabilities" began under the auspices of the Cincinnati Chamber of Commerce; "The Weather Bulletin of the Cincinnati Observatory" began, and maps and bulletins were also published in the daily papers of Cincinnati.

1869. In November Prof. Increase Allen Lapham (*b.* 1811, *d.* 1875) and Hon. H. E. Paine, of the Milwaukee Board of Trade, united with William Hooper and John A. Gano, of the Cincinnati Chamber of Commerce, in securing a resolution by the National Board of Trade, then meeting in Richmond, Va., asking Congress to establish a storm-warning service for all lake ports and sea ports.

1870. February 2. Mr. Armstrong, local manager of the Western Union Telegraph Company, added a manifold weather map to the previous manifold weather bulletin issued at Cincinnati; and these continued until November 10, 1870, when the daily weather map of the Signal Service began. The maps and bulletins issued from the Cincinnati Observatory embraced the region from Wyoming and Texas eastward over the United States, northward to St. Paul, and Southward to Havana.

1870. February 9. The Congress enacted the joint resolution:

"*Be it resolved by the Senate and House of Representatives of the United States of America in Congress assembled*, That the Secretary of War be, and he hereby is, authorized and required to provide for taking meteorological observations at the military stations in the interior of the continent and at other points in the States and Territories of the United States, and for giving notice on the northern lakes and on the seacoast, by magnetic telegraph and marine signals, of the approach and force of storms."

1870. March. The Secretary of War assigns to Gen. A. J. Myer, Chief Signal Officer, U. S. A., the duty of executing the preceding joint resolution. His first step was the establishment of a school of instruction in meteorology at Fort Whipple, now Fort Myer, in addition to the former course in military signaling. This school continued until abolished in 1886 by order of the Secretary of War.

1870. In July. Prof. I. A. Lapham was appointed Assistant Chief Signal Officer, doing duty at Milwaukee and Chicago.

1870. November 1. The inauguration of the Signal Service Circuit System (devised by George C. Maynard) for transmitting station reports simultaneously by telegraph, and the publication of the first weather bulletin of the Signal Service.

1870. November 8, Professor Lapham and Gen. Albert J. Myer (*b.* 1828; *d.* 1880) published the first bulletin announcing storms on the lakes.

1870. December 5. A meteorological station established at the summit of Mount Washington, N. H., in continuation of one started in September, 1870, by the State Geological Survey of New Hampshire. It was maintained by the U. S. Signal Service from December 5, 1870, to September, 1887.

1871. January 3. Prof. Cleveland Abbe was appointed assistant in the office of the Chief Signal Officer, for duty at Washington, D. C.

1871. February 19. First "Weather Probabilities" published by the Signal Service as prepared by Professor Abbe, who continued preparing them thrice daily until February, 1872, when Lieut. Robert Craig, of the Signal Service, began to alternate with him.

1871–1909. U. S. Weather Bureau Forecasts. The regular published weather predictions began February 19, 1871; they were called "Probabilities" and were made three times daily for such elements and periods in advance as seemed warranted by the maps, and for eight geographical districts, viz: New England, Middle States, South Atlantic States, Lower Lakes, Upper Lakes, Eastern Gulf, Western Gulf, and Northwest.

Beginning October, 1872, predictions were made for twenty-four hours in advance and for nine separate districts. During the year ending June 30, 1874, they began to be made for eleven districts and for four elements, viz, weather, wind, pressure, and temperature. During the year ending June 30, 1875, they were made for 10 districts. No change was made until July, 1885, when predictions were made for thirty-two hours in advance or for a twenty-four hour period beginning eight hours after the observation on which they are based. Since July, 1888, predictions have been made thirty-six hours in advance, and beginning August 1, 1898, forecasts based on the evening reports have been regularly made for forty-eight hours in advance. Beginning with May, 1886, predictions have been made by States and parts of States instead of districts. The term "indications" was substituted for "probabilities" on December 1, 1876, and this was changed to "forecasts" on April 1, 1889.

1871. In April, May, and August appeared successive editions of the pamphlet "Practical Uses of Meteorological Reports and Maps, or How to Use the Weather Map."

1871. Commodore M. F. Maury urged that the work of the Signal Service for the prediction of storms on the seacoast and lake ports be extended to include reports and forecasts for the benefit of agriculture.

1871. The appropriation bill authorized additional reports relative to the stages of the water in the rivers. These reports began in 1872.

1871. The Chief Signal Officer delegated Frederick Myers as meteorologist to the polar expedition of Capt. C. F. Hall on the ship *Polaris*. In 1873 Myers returned, having floated 1,800 miles on an icefloe until rescued.

1871. May. The first circulars sent out to captains and owners of vessels requesting tridaily simultaneous observations at sea.

1871. June 18. Thompson B. Maury was appointed assistant in the office of the Chief Signal Officer.

1871. October 23. Institution of a system of "Cautionary" storm and wind signals as supplementary to the text of the "Probabilities."

1871. November 13. Inauguration of a system of international exchange between the Weather Bureaus of the Dominion of Canada and the United States, thus extending our weather maps northward.

1871. December. Prof. A. S. King, aeronaut, offered to take observations on his ascensions and in every way possible to cooperate in the study of the atmosphere. This arrangement continued up to the close of the series of ascensions by him from Philadelphia, in 1885.

1871–72. The Smithsonian Institution published in its Contributions to Knowledge, a discussion by C. A. Schott of its collection of precipitation observations in the United States, Canada, Mexico, and South America. A second edition appeared in 1881.

1872. March. Beginning of the publication of the monthly volumes of weather maps under the title "Synopses, Probabilities, and Facts," which was continued until 1877.

1872. June 10. The appropriations bill provided for "such additional stations, reports, and signals as may be found necessary for the benefit of Agricultural and Commercial Interests."

1872. Three Signal Service stations were opened in the West Indies, to which three more were added in 1874.

1872. September. The "Weekly Weather Chronicle," a summary of features affecting agriculture, as devised and compiled by Henry Calver, began and continued until 1881.

1873. The first, or January, number of the MONTHLY WEATHER REVIEW was published by the U. S. Signal Service as suggested and prepared by Professor Abbe. This monthly was materially enlarged year by year and still continues to be published by the Weather Bureau.

1873. The Signal Service accepted the care of the Dudley Observatory, at Albany, N. Y., as a meteorological station and authorized the local Signal Service observer, Alois Donhauser, to use its apparatus for the determination of local time for public use.

1873. The Surgeon General of the Army, the Secretary of the Smithsonian Institution, and the Chief Engineer of the U. S. Army, relinquished meteorological work and transferred all earlier records to the Signal Service. Thus the climatology of the country was concentrated in the Signal Service archives, and it was enabled to make a corresponding increase in its records and in the completeness of the MONTHLY WEATHER REVIEW.

1873. Gen. Albert J. Myer, as Chief Signal Officer, invited all nations individually through their representatives, to cooperate with him in making and collecting one simultaneous observation daily to be made at 7:35 a. m., Washington time. After several nations had promised cooperation General Myer attended the First International Congress of Meteorology at Vienna in September and requested it to indorse his proposition, which it did.

1873. July 21. A Signal Service station was established on the summit of Pikes Peak, and was maintained to the end of 1888. It was reopened September, 1892, and closed September, 1894.

1873. The "Weather Case," or "Farmer's Weather Indicator" began to be distributed to the country post offices, and the farmers' bulletins displayed at all other post offices, until local flag signals took their place about 1881.

1874. Charts of frequency of storm paths, etc., were prepared by Prof. Cleveland Abbe and published in Walker's Statistical Atlas.

1875. The Smithsonian Institution published Coffin's "Winds of the Globe," with an Appendix by Prof. A. Voeikov.

1875. The beginning of cooperation between the Signal Service and the U. S. Fish Commission in the observation of water temperatures at seaports, lakeports, and river stations.

1875. July 1. The beginning of the publication of the "Bulletin of International Simultaneous Observations." Daily maps were added to this Bulletin in 1877. This bulletin was considered as printed manuscript for exchange with the observers only, and continued daily through 1887, with monthly and annual summaries through 1889. The transfer of marine meteorological work to the Hydrographic Office in 1887 contributed to the interruption of this publication, but the simultaneous observations still continue to be made throughout the world at nearly the same hour, viz, 1 p. m. Greenwich time.

1875. May. The President of the American Metrological Society appointed Prof. Cleveland Abbe chairman of a "Committee on Standard Time." The report of this committee advocating hourly meridians from Greenwich was dated May 20, 1879, and under the leadership of W. A. Allen its recommendations were, with some few changes, put into effect by the railroads of the country on October 7, 1884, a few days before the meeting at Washington of the International Congress on Standard Time.

1875. Prof. Gustavus Hinrichs, of Iowa City, published the first bulletin of the Iowa State Weather Service, which latter was eventually merged into the Iowa section of the Signal Service Weather Bureau.

1876. The Secretary of the Navy ordered simultaneous meteorological observations made on all naval vessels.

1876. Establishment of Signal Service observering stations at Fort St. Michaels and at St. Paul Island, Alaska. By 1882 quite an extensive Alaskan system had developed.

1876. The Smithsonian Institution published in its Contributions to Knowledge, a discussion by C. A. Schott of its collection of temperature observations in the United States. This publication was started in 1874 and completed in 1876.

1877. A section on international meteorology was added to the MONTHLY WEATHER REVIEW.

1877. Establishment of the Central Meteorological Observatory of Mexico and the beginning of its cooperation with the United States service.

1877. The Signal Service contributed to the observing force and apparatus for Arctic work on the schooner *Florence* in Cumberland Sound, which was intended as preliminary to further exploration.

1878. Prof. Francis E. Nipher started the Missouri State Weather Service.

1878. In July the Signal Service occupied the summit of Pikes Peak, Colo., as its station for observing the total eclipse of the sun. The results were published as U. S. Signal Service Professional Paper No. 1.

1879. The U. S. Coast and Geodetic Survey published the "Coast Pilot of Alaska, Appendix I," which was an exhaustive summary of all existing meteorological observations in Alaska. It was prepared by William H. Dall and Marcus Baker in 1878, and was the first adequate presentation of the climatic and meteorologic features of the Territory.

1880. Mr. A. Lawrence Rotch founded the Blue Hill Meteorological Observatory, Hyde Park, Mass., for special research in meteorology.

1880. May. Congress authorized the establishment of a temporary meteorological station at Lady Franklin Bay, but the expedition returned disabled.

1881. February. Lieut. P. H. Ray was assigned to the command of the party designed to occupy the signal station at Point Barrow, Alaska, and sailed from San Francisco July 18. The Point Barrow expedition returned in 1883.

1881. March 11. Lieut. A. W. Greely was assigned to the charge of the second expedition to Lady Franklin Bay and sailed from St. Johns, N. F., on July 7. The surviving members of this expedition were rescued and brought home by Capt. W. S. Schley, U. S. N., in July, 1884.

1881. April 11. The first circular recommending the establishment of independent cooperating State weather services was issued.

1881. July. A Signal Service expedition to the summit of Mount Whitney, Cal., was organized in charge of Prof. S. P. Langley for the study of the sun's heat as received by the atmosphere. The report is published as Signal Service Professional Paper No. XV.

1881. September. Inauguration of a system of "Cotton Belt" observations and reports.

1881. Inauguration of work on the General Bibliography of Meteorology. This work, which has proved to be important to those studying the subject, was pushed forward rapidly until 1893 by which time four sections had been published. (These sections were not printed but mimeographed.)

1881. Inauguration of special warnings for the benefit of the sugar interests of Louisiana.

1881. The two systems of observations that had been thus far maintained—7 a. m., 2 and 9 p. m., local time, and 7:35 a. m., 4:35 and 11 p. m., simultaneous Washington time—were discontinued, and a systematic record at 3, 7, and 11 a. m., 3, 7, and 11 p. m., Washington time, was begun and maintained at nearly all stations until 1884, when it was changed from Washington to seventy-fifth meridian time.

1881–1886. From 1881 to 1886 were published a quarto series of Professional Papers and an octavo series of Signal Service Notes.

1881–1891. Prof. Elias Loomis of Yale University published summaries of the results of his studies of the daily weather map of the Signal Service, in the American Journal of Science.

1881. In this year and during a portion of 1882, the first "local weather forecasts" for publication were made at the New York office of the weather service by E. B. Garriott.

[*To be continued.*]

RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY.

C. FITZHUGH TALMAN, Librarian.

The following have been selected from among the titles of books recently received, as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies. Most of them can be lent for a limited time to officials and employees who make application for them. Anonymous publications are indicated by a ——.

Apia. Samoa Observatorium.
... Ergebnisse der Arbeiten des Samoa-Observatorium der Königlichen Gesellschaft der Wissenschaften zu Göttingen. II. Die meteorologischen Registrierungen der Jahre 1902–1906 von Otto Tetens and Franz Linke. Berlin. 1908. 137 p. 4°. (Abhandlungen der Königlichen Gesellschaft der Wissenschaften zu Göttingen. Mathematisch-physikalische Klasse. Neue Folge. Bd. 17. Nro. 2.)

Batavia. Royal magnetic and meteorological observatory.
Magnetic survey of the Dutch East Indies made in the years 1903–1907 by W. van Bemmelen. Batavia. 1909. 69 p. f°. (Appendix 1 to Observations ... v. 30, 1907.)

Belgium. Observatoire royal.
Annuaire météorologique. 1909. Bruxelles. 1908. vii, 203 p. 24°.

Bosnia-Herzegovina.
Ergebnisse der meteorologischen Beobachtungen. 1906–1907. Sarajevo. 1908. xvi, 173 p. f°.

Delatour, A. J.
A daily record of the thermometer for ten years, from 1840 to 1850, as kept at Delatour's, formerly Lynch & Clarke's, 25 Wall street, New York. New York. 1850. 46 p. 16°.

Denmark. Danske meteorologiske Institut.
Nautisk-meteorologisk Aarbog. Kobenhavn. 1909. lii, 169 p. f°.

Egypt. Survey department.
Meteorological report 1906. Cairo. 1908. v. p. f°.

Fortschritte der Physik.
1te Abtheilung. 1908. Braunschweig. 1909. xxxii, 573 p. 8°.

Ghent. Université.
Annuaire météorologique de la Station de géographie mathématique. Mars 1908–Février 1909. Roulers. 1909. 91 p. 12°.

Greifswald. Meteorologische Station.
Die Ablesungen der meteorologischen Station Greifswald vom 1. Januar bis 31. Dezember 1908 nebst Jahresübersicht über das Jahr 1908. Greifswald. [1909.] 50 p. 8°.

Hamburg. Hauptstation für Erdbebenforschung am Physikalischen Staatslaboratorium.
Calabrisch-sizilianisches Erdbeben am 28. Dezember 1908. I & II. 2 sheets. 27 x 100 cm.
Erdbeben in Persien (Provinz Luristan) am 23. Januar 1909. 1 sheet. 27 x 93 cm.
Vogtländische Erdbebenstösse am 4. und 6. November 1908. 1 sheet. 27 x 100 cm.

Haute-Garonne. Commission météorologique.
Bulletin. Tome 2. 1er fasc. 1906. Toulouse. 1908. 58, [169] p. 4°.

India. Board of scientific advice.
Annual report. 1907–08. Calcutta. 1909. iii, 182 p.

India. Meteorological department.
Rainfall of India. 1907. Calcutta. 1908. v. p. f°.

International meteorological committee.
Codex of resolutions adopted at international meteorological meetings, 1872–1907. Prepared at the request of the International meteorological committee, by H. H. Hildebrandsson and G. Hellmann. London. 1909. 80 p. 8°.

Jahrbuch der Astronomie und Geophysik.
19 Jahrgang 1908. Leipzig. 1909. viii, 384 p. 8°.

Japan. Central meteorological observatory.
Annual report. 1906. pt. 1. [Tokyo. 1909.] f°.

Mache, H., & Schweidler, E. v.
... Die atmosphärische Elektrizität. Methoden und Ergebnisse der modernen luftelektrischen Forschung. Braunschweig. 1909. xi, 245 p. 8°. (Die Wissenschaft. Sammlung naturwissenschaftlicher und mathematischer Monographien. Heft 30.)

Nice. Observatoire.
... Annales. Tome 11. Paris. 1908. v. p. f°.
Same Tome 13. 1er fasc. Paris. 1908. v. p. f°.

Norwegian aurora polaris expedition 1902-1903.
v. 1. On the cause of magnetic storms and the origin of terrestrial magnetism, by Kr. Birkeland. Christiania. [1908.] vi, 315 p. f°.

Paris. Observatoire municipal. Montsouris.
Annales. v. 7. Paris. 1906. 535 p. 4°.
Annales. v. 8. Poris. 1907. 423 p. 4°.

Prager, Walter.
Rumänien's landwirtschaftliche Klimatographie. Halle a S. 1909. 203 p. 8°.

Prague. K. k. Sternwarte.
Magnetische und meteorologische Beobachtungen. 1908. 69. Jahr. Prag. 1909. 47 p. f°.

Russia. Central physical Nicholas observatory.
Annales. 1905. 1er partie. St. Petersburg. 1908. v. p. f°.
Annales. 1905. 2me partie. St. Petersburg. 1908. v. p. f°.
Annales. 1905. 3me partie. St. Petersburg. 1908. v. p. f°.

Schellenberg, Osmar.
Studien zur Klimatologie Greichenlands. Temperatur, Niederschläge, Bewölkung. Leipzig. 1908. 98 p. 8°. (Inaug.-diss.-Leipzig.)

Switzerland. Schweizerische meteorologische Central-Anstalt.
Annalen ... 1907. Zürich. [1909.] v. p. f°.

Tacubaya. Observatorio astronomico nacional.
Observaciones meteorologicas 1897. Mexico. 1909. 239 p. f°.

Uruguay. Instituto meteorologico nacional.
Promedios mensuales. Año 1908. [Montevideo. 1909.] 1 sheet. 42 x 83 cm.

Zi-ka-wei. Observatoire.
Code des signaux. Changhai. 1909. 13 p. 24°.
Signaux aux marins. Changhai. 1909. 23 p. 8°.

RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY.

C. FITZHUGH TALMAN, Librarian.

The subjoined titles have been selected from the contents of the periodicals and serials recently received in the Library of the Weather Bureau. The titles selected are of papers or other communications bearing on meteorology or cognate branches of science. This is not a complete index of the meteorological contents of all the journals from which it has been compiled; it shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau. Unsigned articles are indicated by a ——

American journal of science. New Haven. 4th ser. v. 27. April, 1909.
Perret, Frank A. Preliminary report of the Messina earthquake of December 28, 1908. p. 321–334.

California physical geography club. Bulletin. Berkeley. v. 2. March, 1909.
Rowell, Percy E. The San Rafael high school weather observations. p. 6–9.

India. Meteorological department. Memoirs. Calcutta. v. 18, pt. 2.

Eliot, Sir John. A description of the anemographic observations recorded at Saugor Island from March, 1880, to February, 1904. p. 123–214. [Includes a description of the climate.]

Eliot, Sir John. A discussion of the anemographic observations recorded at Alipore (Calcutta) from March, 1877, to February, 1904. p. 215–282. [Includes a description of the climate.]

Nature. London. v. 80. 1909.

Dines, W. H. Meteorological observations [of Lieutenant Shackleton's antarctic expedition]. (Apr. 1.) p. 133–134.

Berson, A. The Royal Prussian aeronautical observatory's aerological expedition to tropical east Africa. (Apr. 8.) p. 171–172.

Teisserenc de Bort, L. & Rotch, A. Lawrence. General results of the meteorological cruises of the *Otaria* on the Atlantic in 1905, 1906, and 1907. (Apr. 22.) p. 219–221.

London, Edinburgh, and Dublin philosophical magazine. London. 6 series. v. 17. April, 1909.

Simpson, George C. On the Wilson-Gerdien theory of thunderstorm electricity. p. 619–634.

Wilson, C. T. R. On thunderstorm electricity. p. 634–641.

Royal society. Proceedings. London. ser. A. v. 82. 1909.

Simpson, George C. On the electricity of rain and its origin in thunderstorms. p. 169–172. [Abstract.]

Royal meteorological society. Quarterly journal. London. v. 35. April, 1909.

Mill, Hugh Robert. Some aims and efforts of the Royal meteorological society in its relation to the public and to meteorological science. p. 65–79.

—— Meteorology at Harvard university. p. 79–80.

—— Hail insurance. p. 89–90.

Köppen, W. Proposal to express all measurements of atmospheric pressure by a universal measurement of force. p. 132–134.

Newman, T. P. Temperature and rainfall at Pemba, E. Africa. p. 139–140.

Science. New York. v. 29. Jan. 29, 1909.

Very, Frank W. The presence of water vapor in the atmosphere of Mars demonstrated by quantitative measurements. p. 191–193.

Scientific American supplement. New York. v. 47. April 17, 1909.

Joly, John. Underground temperature and radium. Is the one due to the other? p. 246.

Tokyo mathematico-physical society. Proceedings. Tokyo. v. 5. Feb., 1909.

Homma, V. Ueber eine Gewitterperiode. p. 12–42.

Aérophile. Paris. 17 année. 1 mai 1909.

Mastrand, A. de. Un institut d'aérodynamique en Russie. p. 194–197.

Annales de géographie. Paris. 18 année. 15 mars 1909.

Voeikov, A. Projets d'organisation de services scientifiques en Russie. p. 183–184. [Note on the meeting of Russian meteorologists at St. Petersburg. Jan., 1909.]

Ciel et terre. Bruxelles. 30 année. 1 avril 1909.

Boutquin, A. L'Asie centrale. p. 60–63.

France. Académie des sciences. Comptes rendus. Paris. Tome 148. 1909.

Millochau, G. Contribution à l'étude du rayonnement. (22 mars.) p. 780–782.

Féry, C. Détermination de la constante de la loi de Stefan. (5 avril.) p. 915–918.

Halluitte, —. Orage sur mer. (19 avril.) p. 1066.

Angot, Alfred. Sur la valeur et la variabilité des moyennes barométriques. (26 avril.) p. 1131–1133.

Angot, Alfred. Sur le tremblement de terre du 23 avril 1909. (26 avril.) p. 1133.

Géographie. Paris. Tome 19. 15 février 1909.

Rabot, Charles. Le tremblement de terre du 28 décembre 1908 en Sicile et en Calabre. p. 128–131.

Nature. Paris. 37 année. 10 avril 1909.

Troller, A. La dispersion des brouillards. p. 289–291.

Société belge d'astronomie. Bulletin. Bruxelles. 14 année. 1909.

Nodon, A. L'origine solaire des cyclones et des tempêtes. (mars.) p. 121–123.

Arctowski, Henryk. Variations de la répartition de la pression atmosphérique à la surface du globe. (mars.) p. 161–163.

Durand-Gréville, E. L'aube et l'albe. Premier crépuscule du matin et second crépuscule du soir. (avril.) p. 163–173.

Illustrierte aeronautische Mittheilungen. Strassburg. 13. Jahrgang. 1909.

Berson, A., & Elias, H. Die Ostafrika Expedition des Königlich aeronautischen Observatoriums. (April 7, 21.) p. 219–223; 301–309.

Meteorologische Zeitschrift. Braunschweig. Band 26. März 1909.

Miethe, A., & Lehmann, E. Dämmerungsbeobachtungen in Assuan im Winter 1908. p. 97–114.

Woeikow, A. Temperatur ostsibirischer Flüsse und eines Polarsees daselbst. p. 114–118. [Abstract of two papers by Schostakowicz.]

Woeikow, A. Die meteorologische Station Vassijaure in Schwedisch-Lappland. p. 118–120.

Exner, Felix M. Neue Strahlungsuntersuchungen aus dem Astrophysikalischen Observatorium der Smithsonian Institution. p. 120–129. [Abstract.]

Pollack, Vincenz. Gebirgswinter und Lawinenfall. p. 129–130.

Braak, C. Beobachtungen über Richtung und Geschwindigkeit des Cirruszuges in Batavia. p. 130.

Exner, Felix M. Knut Ångströms neue Methode zur Untersuchung der Sonnenstrahlung. p. 131–133.

—— Pringal, E. Ueber den wesentlichen Einfluss von Spuren nitroser Gase auf die Kondensation von Wasserdampf. p. 133–135. [Abstract.]

—— Richarz, F. Ueber den wesentlichen Einfluss von Spuren nitroser Gase auf die Kondensation von Wasserdampf. p. 135. [Abstract.]

H[ann], J[ulius]. Klima von Monastir. p. 136.

H[ann], J[ulius]. Klima von Lourenço Marques, Mozambique. p. 136–137.

Hann, J. Resultate der meteorologischen Beobachtungen zu Harar 1902 bis 1904. p. 137–138.

Maurer, J. Rübel, E.: Untersuchungen über das photochemische Klima des Bernina-Hospizes. p. 139–140. [Abstract.]

Meteorologische Zeitschrift. Braunschweig. Band 26. April 1909.

Alt, E. Die Doppeloszillation des Barometers, insbesondere im arktischen Gebiete. p. 145–164.

Maurer, J. Aus langjährigen Aufzeichnungen des Schweizer Föhns. p. 165–170.

Wagner, A. W. J. Humphreys: Die vertikalen Temperaturgradienten in der Atmosphäre. p. 172–174.

Fitzner, —. Mittlere Regenmessungen und Mitteltemperaturen für Deutsch-Togo. p. 175.

—— Resultate der meteorologischen Beobachtungen zu Hebron (Palästina) im Jahre 1907. p. 178.

—— Resultate der meteorologischen Beobachtungen zu Buitenzorg im Jahre 1907. p. 181.

Schmidt, Wilhelm. Eine unmittelbare Bestimmung der Fallgeschwindigkeit von Regentropfen. p. 183–184.

Hann, J[ulius]. Resultate meteorologischer Beobachtungen zu Bolobo am Congo. p. 185–186.

Prometheus. Berlin. 20. Jahrgang. 1909.

Kurz, Karl. Elektrizität der Atmosphäre und Radioaktivität der Atmosphäre. (14, 21, 28 April) p. 438–442; 449–452; 465–469.

Wetter. Berlin. 26. Jahrgang. März 1909.

Hoffman, J. F. . Die Veränderung des Grundwasserstandes und die Volgersche Theorie. p. 49–60.

Joester, Karl. Die Föhnerscheinungen im Riesengebirge. p. 60–62.

Wetter. Berlin. 26. Jahrgang. April 1909.

Schubert, J. Die Witterung in Eberswalde im Jahre 1907. p. 73–79.

Joester, Karl. Die Föhnerscheinungen im Riesengebirge. p. 79–84.

Gockel, A. Zusammenhang zwischen Blitz und Regenintensität. p. 89.

Wiener Luftschiffer-Zeitung. Wien. 8. Jahrgang. 15. April 1909.

Hinterstoissier, —. Die Konferenz in Monaco. (Sechste Konferenz der Internationalen Kommission für wissenschaftliche Luftschiffahrt in Monaco vom 30. März bis 6. April 1909.) p. 134–135.

Hildebrandt, D. Das Observatorium auf Teneriffa. p. 135–137.

Hemel en dampkring. Amsterdam. 6. Jaargang. April 1909.

—— Volkswijheid over het weer. p. 191–192. [Gives a number of Dutch weather proverbs.]

Koninklijk Nederlandsch meteorologisch Institut. Mededeelingen en Verhandelingen. Utrecht. No. 6. 1908.

Everdingen, E. van. De uitkomsten der weersverwachtingen van het Koninklijk Nederlandsch meteorologisch Institut in 1904 en 1905, en in den Zomer van 1907. p. 3–26.

Académie impériale des sciences. Bulletin. St. Petersburg. 6 sér. mars 1909.

Galitzin, B. Das Sicilianische Erdbeben am 28. Dezember 1908 nach den Aufzeichnungen der Pulkowa'schen seismischen Station. p. 279–298.

Società aeronautica Italiana. Bollettino. Roma. Anno 6. Marzo 1909.

Eredia, F. I venti in Italia. p. 96–108.

—— Il movimento ondoso degli strati atmosferici. p. 24–25.

—— Misure di ionizzazione dell'aria su terraferma ed in mare. p. 125–127.

Società geografica Italiana. Bolletina. Roma. ser. 4. v. 10. Aprile 1909.

De Castro, Lincoln. La città e il clima di Addis Abeba. p. 409–442. [Illustrated.]

—— Note sul clima e sull'idrografia della Somalia italiana (Benadir). p. 455–457.

Sociedade de geographia de Lisboa. Boletin. Lisboa. 27. ser. Fev. 1909.

Gomes de Sousa, Ernesto. Resumo das observaçoes no anno de 1908 no observatorio de Loanda. p. 76.

HIGH WINDS IN OHIO.

[Extract from the Monthly Climatological Report, Ohio Section, April, 1909.]

The total wind movement for the month of April was unusually great and there were a number of very damaging storms.

On the 7th the wind reached a velocity of 60 miles an hour at Columbus, 40 miles an hour at Sandusky, and 70 miles an hour at Toledo. Much damage was done in the northern counties to telegraph and telephone wires, buildings, and trees. It was reported to be one of the most severe April storms for many years on Lake Erie.

Thunderstorms were general on the 21st and were accompanied by high winds at most places. A maximum wind velocity of 54 miles an hour was recorded at Columbus, with an extreme velocity of 68 miles an hour for one minute. At Cleveland on this date the wind attained the hurricane velocity of 66 miles an hour from 12:33 to 12:38 p. m., and of 84 miles an hour for one minute at 12:34 p. m.

This storm had many of the characteristics of a tornado in the northern portion of the State, except that no funnel-shaped cloud was observed. At Berea, in western Cuyahoga County, however, the cloud was described as a rolling or tumbling cloud. The path of greatest damage, so far as reports to this office show, was from Crawford County northeastward to Lake County. The high wind was reported in Crawford County at 11:30 a. m., in Lorain County at 12 m., in western Cuyahoga County at 12:15 p. m., at Cleveland at 12:33 p. m., and in Lake County at 1:30 p. m.

In most places the trees, buildings, etc., were blown directly toward the northeast, the path of greatest damage was wider than is usually made by a tornado, and there were other indications that the wind was a straight-line squall wind rather than a true tornado. At Berea, however, houses on the south side of the path of greatest damage were blown first toward the north and then toward the northeast. At Olmsted Falls, also, some of the damaged stones in a cemetery were blown toward the north and others toward the east. These facts indicate the rotary winds that accompany a true tornado.

A great deal of damage occurred in this storm, especially in Cleveland, where it was estimated to be over $1,000,000. Four people were killed in this city and many others were injured. [See details on page 153.]

High winds were general in the southern and western portions of the State on the night of the 29th. At Sidney, in Shelby County, a conservative estimate places the loss at $60,000. The path of greatest damage in this city was only from 150 to 200 feet in width, and there were other evidences of a true tornado. Several eye witnesses state that the cloud looked like gigantic rolling pins or "sea-wheels." The storm there was from 11:45 p. m. to midnight.—*J. W. Smith.*

SNOWFALLS AND WATER EQUIVALENTS IN NEW YORK.

In the MONTHLY WEATHER REVIEW for January, 1907, p. 11, Mr. Robert E. Horton,[1] resident engineer of the New York State Barge-canal Office, voiced the desirability of securing special snowfall measurements and determinations of true water equivalents, pointing out statistically that the measured winter runoff of the West Canada Creek Basin (Mohawk System), always exceeded the measured precipitation of that basin for the same season. He had already established stations designed to correct this discrepancy, and we are glad to present in the following table the results of these accurate snowfall measurements and water equivalents as recorded at Hoffmeister during the winters from 1905 to 1908, under his direction. In his letter of June 4, 1909, Mr. Horton describes Hoffmeister as being one of the localities where the snowfall is deepest.—*H. C. F.*

[1]For other papers bearing on the relation between snowfall and winter stream discharge in the Adirondacks, see Monthly Weather Review, May, 1905, **33**:196-202, and January, 1907, **35**:8-11.

TABLE 1.—*Showing water equivalent of accumulated snow on ground at Hoffmeister, West Canada Creek Drainage Basin.*

Winter of 1905–6.			Winter of 1906–7.		
Date.	Snow on ground.	Water equivalent.	Date.	Snow on ground.	Water equivalent.
1906.	*Inches.*	*Inches.*	1906.	*Inches.*	*Inches.*
January 7	14.5	3.2	December 10	2.0	0.42
14	20.5	4.0	17	3.0	0.65
21	25.0	4.9	24	3.5	0.70
28	15.0	4.9	30	4.0	0.75
February 4	18.0	6.0*	1907.		
12	20.0	6.6*	January 7	3.0	0.55
18	23.0	7.6*	14	7.0	0.60
25	15.0	5.0*	21	6.0	0.49
March 4	19.0	7.5	28	12.0	4.4
11	17.0	8.0	February 4	20.0	7.4
18	21.0	8.2	11	22.0	4.5
25	31.0	15.0	18	29.0	4.7
April 2	26.0	8.0	25	34.0	4.9
9	22.0	7.4	March 4	37.0	5.0
16	17.0	6.6	5	38.0	4.7
23	0.0	0.0	11	37.0	5.3
			18	32.0	5.7
			24	24.0	7.4
			April 1	14.0	4.2
			8	10.0	4.2
			15	13.5	5.6
			22	13.0	5.7
			29	8.0	4.4

Winter of 1907–8.			Winter of 1908–9.		
1907.			1908.		
December 2	11.0	1.5	November 30	0.0	0.0
9	10.0	1.8	December 7	11.0	2.2
16	12.0	2.7	14	17.0	2.3
23	15.0	3.4	21	23.0	2.4
30	11.5	3.1	28	22.0	5.5
1908.			1909.		
January 6	21.0	3.6	January 4	27.5	6.7
13	23.5	3.8	11	19.0	5.6
20	26.5	4.5	18	38.0	6.7
27	27.0	4.8	25	26.5	8.2
February 3	42.0	4.3	February 1	32.0	6.8
10	58.0	6.0	8	27.0	4.9
17	35.0	7.2	15	30.0	8.6
24	40.0	8.1	22	32.0	9.1
March 2	48.0	9.6	March 1	34.5	11.3
9	52.0	7.0	8	39.0	9.3
16	42.5	11.5	15	43.0	9.6
23	43.0	6.7	22	46.0	11.1
30	28.5	6.0	29	54.0	12.0
April 6	30.0	9.6	April 5	48.0	8.3
13	25.5	7.1	12	42.0	9.5
20	20.0	8.7	19	26.0	6.3
27	9.0	8.6	26	15.0	5.2
May 4	0.0	0.0			

* These figures were obtained by dividing the snow accumulation by 3.0, the snow sample not having been melted by the observer in these cases.—*R. E. H.*

TORNADO IN ILLINOIS.

At 5:40 to 5:45 a. m., April 6, a tornado visited Marion and Halfway, Williamson County, Ill., doing about $8,000 damage, but without causing any injuries to persons in its path. The storm occurred at Marion at 5:40 a. m., but the destructive tip of the funnel-shaped cloud was 50 to 100 feet above the earth, so the damage was mostly to roofs and the upper stories of buildings. The width of the path here is put at 100 to 200 yards. At 5:45 a. m. the storm had reached Halfway, about 15 miles to the northeast. Here the observer reports that there was a well-defined funnel-shaped cloud 30 to 40 feet in diameter, but that most of the damage was done by a straight wind which accompanied the whirl.—*C. A., jr,*

TORNADOES IN KANSAS.

A severe tornado occurred near the border of Cowley and Butler counties on the 28th. It was first noted at 6:05 p. m. 1 mile west of Udall, in the northwest part of Cowley County, and was moving northeastward. At about 6:15 p. m. it struck Douglas, about 11 miles northeast of Udall, in the southern part of Butler County, and much damage was done. One person was killed and one badly injured. The damage at Udall is estimated at $14,000 and at Douglas from $25,000 to $40,000.

On the 29th a small tornado struck Cooperative Observer J. Clarence Norton at Moran, Allen County, Kans., while working in a field, at 3:37 p. m. He writes:

> The tornado reported by me was a small one and originated 1 mile west of me and did not hit any buildings or trees in its course. It was 50 yards wide, came down out of a fair sky, and when it hit the plowed land the dust rose in such amounts as to make all in its path as dark as night.
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> It took all my strength to keep it from sucking me off the lister.[1] The terrific wind and suction and ice-cold center of the inky black whirling mass of dust and cornstalks was indeed terrifying, and my team and myself were surely alarmed. The lister was all that held the team down. Half a mile east of here the tornado rose up.

No material damage seems to have been done, and this storm was dissipated before reaching any other person or any buildings.

A tornado occurred in the east-central part of Butler County and passed to the west-central part of Greenwood County, Kans., on February 22, 1909. The storm destroyed about $10,000 worth of property and injured six or eight persons, but so far no deaths have been reported.—*C. A., jr.*

TORNADOES IN TENNESSEE.

[Extract from Monthly Climatological Report, Tennessee Section, April, 1909.]

Violent thunderstorms and tornadoes occurred on the afternoon of April 29 and the night of the 29–30th at many places in Tennessee, in connection with the passage of an area of low atmospheric pressure of unusual depth and extent, the center of which moved from Kansas (7 a. m., 29th) to Michigan (7 a. m., 30th). This low pressure area, or storm center, at 7 a. m. April 29, was the controlling influence in the weather conditions over the entire central portions of the country, from the Rocky Mountains to the Allegheny Mountains. In its south and east quadrants unusually high temperatures prevailed at 7 a. m., with light to brisk southerly winds; but very little rain had fallen, the sky being generally partly cloudy to cloudy. About the center of the low pressure area, in Oklahoma and Kansas, there was a sharp contrast in temperature; for example, at Oklahoma the temperature was 72°, while at Amarillo it was 50°; at Kansas City it was 72°, while at Dodge City it was 48°. West of the center of the low pressure area temperatures were moderately low. The conditions were favorable for thunderstorms and squalls in Tennessee, as was stated in the forecast printed on the weather maps of the morning of April 29.

The first violent winds seem to have occurred about 2 p. m. in Hamilton County. This disturbance apparently moved northeastward and reached the vicinity of Knoxville about 4 p. m.

The most clearly defined and the longest tornado track, see fig. 1, *1*, was made across the State from the extreme southwest corner northeastward to Scott County. This tornado came from Mississippi, struck White Haven, Shelby County, Tenn., at 7:30 p. m.; struck a section a few miles east of Somerville, Fayette County, at about 8:30 p. m.; vicinity of Henderson, Chester County, about 9 p. m.; vicinity of Centerville, Hickman County, about 10:30 p. m.; Hillsboro and Franklin, Williamson County, about 11 p. m.; Algood and Cookeville, Putnam County, about 1 a. m. (30th). The width of this track varied from a few hundred yards to about one mile.

A second well defined tornado track, see fig. 1, *2*, extended from the vicinity of Cuba, Shelby County, northeastward through Haywood, Gibson, Carroll, Humphreys, Dickson, and Montgomery counties. This track was parallel with *1*, and the time of occurrence of the tornado was about the same. Its width varied from about 200 yards to about 2 miles.

A third track, see fig. 1, *3*, extended through Giles and Lincoln counties northeastward, the tornado being apparently dissipated in the mountains. It struck the vicinities of Pulaski, Bryson, and Fayetteville about midnight. Its track was about one-half mile wide as it passed through the southern part of Giles County.

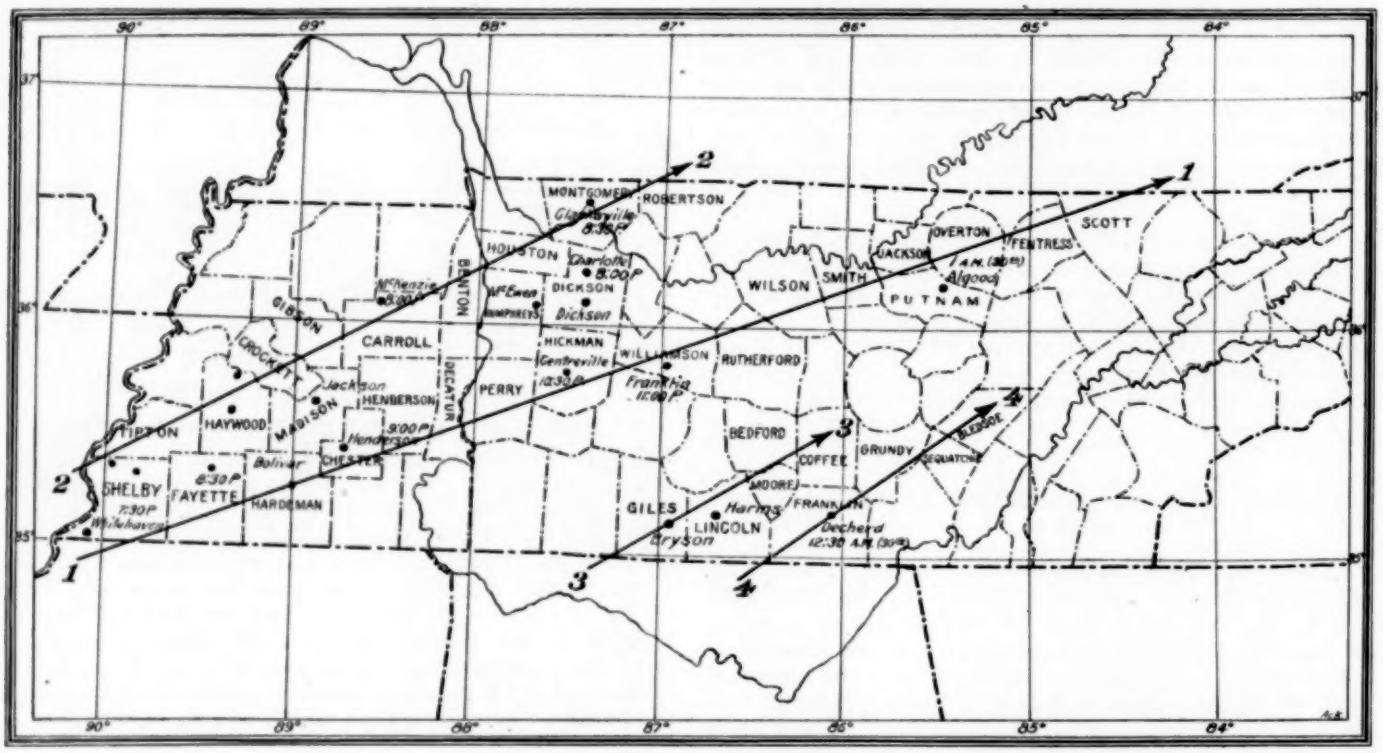

FIG. 1.—Tornado paths across Tennessee, April 29, 1909.

[1] A special kind of plow having a double mould board.

A fourth track, see fig. 1, *4*, passed through Franklin County, the tornado striking Decherd about 12:30 a. m., April 30, and apparently passing, with diminished violence, through Grundy and Meigs counties. Its track was about 2 miles wide at Decherd.

Each of these terrific disturbances was accompanied by the usual distinctive marks of the tornado—pendant funnel-shaped cloud, narrow path, destructive violence and scattering of debris in all directions.

Deaths were reported as follows: Giles County, 22; Lincoln County, 7; Williamson County, 8; Montgomery County, 4; Chester County, 4; Hickman County, 10; Franklin County, 4; Hardeman County, 1. The list is not complete for the State. A hundred or more people were reported injured, a number fatally. The property loss was estimated as follows: Giles County, $100,000; Lincoln County, $100,000; Montgomery County, about $25,000; Williamson County, $100,000; Chester County, about $15,000; Shelby County, about $150,000; Hickman County, $150,000; Algood and vicinity, about $10,000; Decherd and vicinity, about $150,000; Bolivar and vicinity, about $5,000. The losses are not all reported, and the amounts given are only approximately correct.—*H. C. Bate.*

TORNADOES IN MISSISSIPPI.

By W. S. BELDEN, Section Director.

On the evening of April 6 a tornado passed through the suburbs of Aberdeen, Miss., killing five persons, seriously injuring several others, and destroying considerable property.

At about 7:30 p. m. April 29 a tornado approximately one-half mile in width and moving in an easterly direction passed through the villages of Horn Lake and Plumpoint, which are located in the extreme northern portion of De Soto County, Miss. Six persons were killed by the storm, four or five injured, and the loss of property was heavy. This storm also did considerable damage in Tennessee.

SEVERE LOCAL STORM AT CLEVELAND, OHIO.

By JAMES KENEALY, Local Forecaster. Dated Cleveland, Ohio, May 22, 1909.

On the morning of April 21 the daily weather map showed a deep cyclonic trough extending from the Texas coast to Lake Superior, with the disturbance central near Springfield, Ill., where the barometer then stood at 29.40 inches. At 7 p. m. of that day the telegraphic reports showed the axis of the barometric trough to have advanced to a north-south line extending through Lakes Huron and Erie and the upper Ohio Valley, with the center of the depression located near Saugeen, Ontario, from which station a barometric reading of 29.24 inches was reported. The local storm at Cleveland occurred between noon and 1 p. m., in the southeast quadrant of the cyclone whose center was then passing northeastward near the southern border of Michigan. At Cleveland the day began with cloudy and threatening weather, light winds from the east, with the temperature stationary at 43° during the hours from midninght to 4 a. m., the morning minimum. The barometer fell slowly during the hours from midnight to 7 a. m., and the barograph showed a few slight oscillations in the pressure during that period. At 7 a. m. the temperature had risen to 46° and the wind had veered to southeast, increasing to a velocity of 20 miles per hour, with gradually diminishing pressure. Light rain began at 7:05 a. m. and ended at 9:30 a. m., the shower giving a total rainfall of 0.14 inch. A few rumbles of thunder were heard in the northeast about the time the shower ended. By 8 a. m. the temperature was beginning to rise quite rapidly, with fast diminishing pressure. The southeast wind steadily increased and a squall between 10 and 11 a. m. attained a velocity of 42 miles per hour for five minutes. From this time till noon the wind gradually decreased to moderate, with generally cloudy weather, though a few minutes of sunshine had followed the shower. The temperature had risen from 43° at 4 a. m. to 51° at 9 a. m., reaching 68° at noon, its maximum for the day, while the barometer had fallen from 28.97 inches to 28.59 inches during the same interval.

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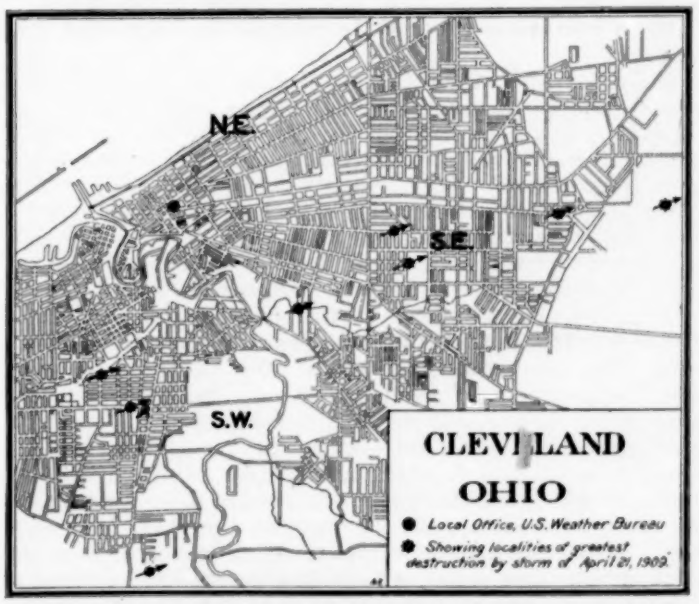

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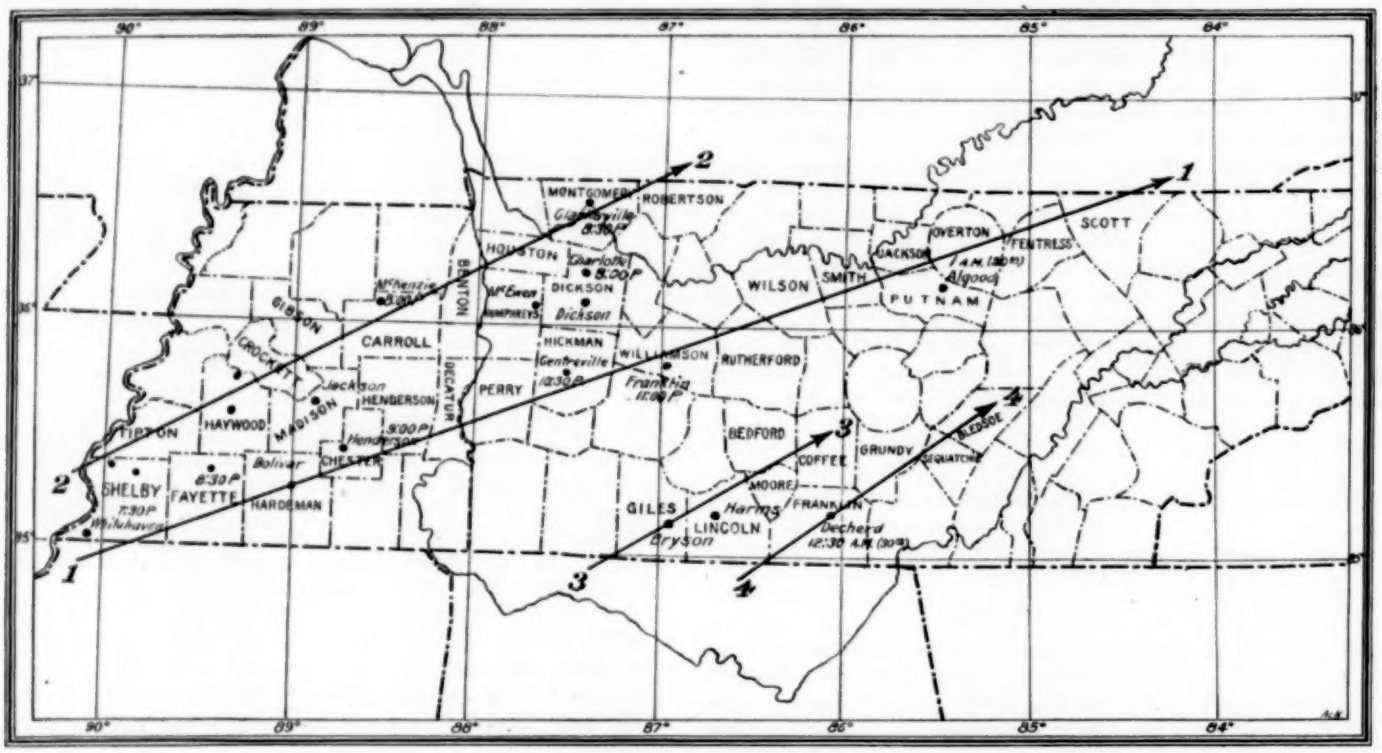

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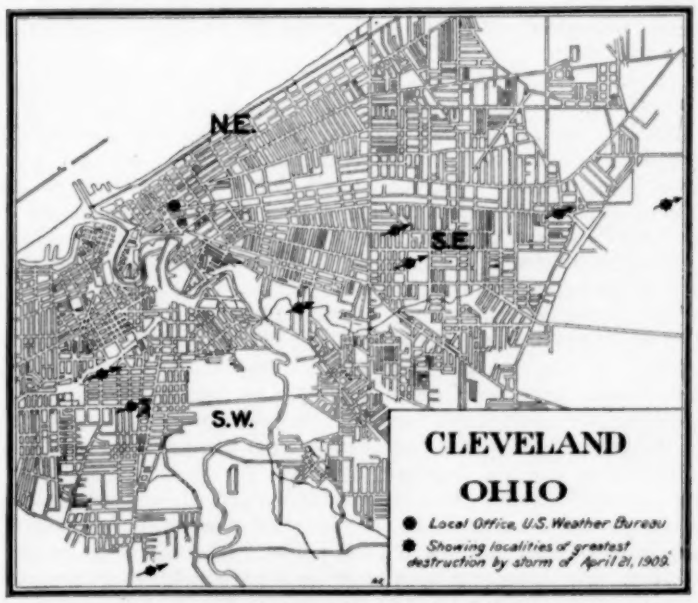


FIG. 1.—Path of storm through Cleveland, Ohio, April 21, 1909.

Casualties and damage to property.—Considering the number of persons killed and injured and the damage to property, the storm was the most disastrous that the city has ever suffered. Seven persons were killed by flying debris, collapsing build-

ings, or being blown from their foothold; but one was so terrified that he committed suicide. About 50 other persons were badly injured and two were struck by lightning. The damages amount to a total estimated loss of $1,000,000, of which $500,000 was principally sustained by a few large manufacturing establishments, twelve churches and seventeen schoolhouses, nearly all of which were located in the southeast or the southwest sections of the city. The railway and telephone lines operating in these sections were also heavy losers by injuries to their property. The northeast and northwest sections of the city suffered only small loses through damage to property, but even in these sections some roofs of buildings were injured and windows broken, and at *A*, fig. 1, "every telephone and trolley post on the west side of the street for 8 blocks was either blown down or badly damaged."

Reports received by the local newspapers showed that on the day of this storm considerable damage was done by thunderstorms in the adjacent county (Loraine) on the west and at places in the belt of counties extending thence northeast to Ashtabula County. At Elyria, according to a report, "Windows were blown in and outbuildings and sheds wrecked." At Medina, "Trees in the public square were uprooted, telegraph poles were blown down and roofs and chimneys wrecked." At Ashtabula, "One house was turned completely upside down and demolished. The roof of the Lyceum Theater was carried over residences and shot through North Park, trees being stripped in its path;" also, "A house was blown from its foundation, barns and small buildings all over the city were unroofed and completely razed." In Plymouth, Ashtabula County, "A man who sought shelter in a horse shed during a thunderstorm was killed by the collapse of a church near by, and another man who had sought shelter in the same shed was knocked senseless, and one of his arms was broken."

It seems probable that if the hours of occurence of these disturbances, and others on the same day in northern Ohio, could be learned the facts might show that the Cleveland storm originated in one of the counties of northwestern Ohio and traveled thence through this city into Ashtabula County. However, it would probably be impossible to trace the connection between these local storms, owing to the lack of reliable observations of time, barometric readings, and other essential data.

It is believed that the Cleveland storm should properly be classed as an exceptionally severe local storm, but not as a tornado. So far as can be learned, no one saw the funnel-shaped tornado cloud when this storm was advancing or after it had passed. There were but few flashes of lightning. Objects, such as trees or poles that had been overturned by the wind, were found to lie in a direction from southwest to northeast, or west to east, and in the majority of cases they lay toward the east. In a few instances heavy roofing of tin or other material had been carried from one roof to another 100 to 200 feet distant, and they were carried from west to east. In the grove near the Euclid Club, where about 100 trees, large and small, were found uprooted and blown over within an area not larger than four acres, the trunks lay as if overturned by a southwest or west wind. Near the same club house an iron flagstaff, 4 inches in diameter, had been blown nearly prostrate in a northeastward direction, the wind having bent the iron near the base of the staff. Among all the hundreds of houses where panes of window glass were broken out, there seems to have been no breaking by outward expansion of the air, though there were windows fronting east that had their glass broken and forced outward, this effect being probably due to the west squall having reached them through open doors or windows in the rear of the house. So far as can be learned no chickens were stripped of their feathers, nor were any trees stripped of their bark. For these reasons, and notwithstanding the great destructive force that the wind attained at many places within a zone of 1 to 2 miles in width and 6 miles long within the city and its outskirts, it seems proper to assume that the storm was not a tornado.

TORNADO IN ALABAMA.

By E. C. HORTON, Assistant Observer. Dated: Montgomery, Ala., May 21, 1909.

I have the honor to submit the following report of a tornado that occurred in the northern part of Alabama near midday of April 30, 1909.

The storm began about 7 miles southeast of Moulton, Lawrence County, and moved in a northeasterly direction to about 1½ miles north of Danville, Morgan County, where it seems to have disappeared.

The storm track varied from 100 yards to a half mile in width. The tornado was well defined, having the characteristic funnel-shaped cloud, with the usual destructive effects. At Madison it seems to have been represented by a severe hailstorm. Only one person was killed, but about eighteen were more or less injured. Seven dwellings were demolished, their value being estimated at $4,000. The damage to timber and other property was also great, and the loss in livestock was considerable. It would probably be conservative to place the entire property loss at not less than $15,000.

TORNADOES IN ARKANSAS.

[Extract from the Monthly Climatological Summary, Arkansas Section, March, 1909.]

February, 1909.

At 8 a. m., seventy-fifth meridian time, February 5, 1909, a low of large geographic extent and great intensity extended from the Lake region to Texas, the center of the storm being over Davenport, Iowa, with a pressure of 29.24 inches. At that hour Arkansas was in the southeast quadrant of the storm and the weather, which was abnormally warm, damp, and blustery, with thunderstorms at many places, was favorable for the development of tornadoes.

Between 8 and 9:30 o'clock in the morning tornadoes passed over Hamburg, Ashley County, and Stuttgart, Arkansas County. At Hamburg there was no loss of life and no one was injured, but two brick buildings were damaged, the loss in buildings and merchandise being estimated at $6,000. The tornado that passed over Stuttgart killed two persons and injured several others, and two residences and six barns were destroyed. At Little Rock, Pulaski County, a thunderstorm, accompanied by rain, hail, and high wind, prevailed from 7:02 to 9:30 a. m., a maximum velocity of 52 miles per hour from the northwest being recorded at 7:12 a. m. No damage resulted in the city from this storm.

During the early morning of February 23, 1909, a destructive tornado passed over portions of Lonoke, Prairie, Woodruff, Jackson, and Poinsett counties. The weather map of February 22 showed a storm of great intensity central over Colorado, while a secondary disturbance overlay southwestern Texas. These storms, following their usual paths, had moved during the next 24 hours to western Missouri and central Arkansas, respectively.

In Arkansas the weather was cloudy, the temperature much above the normal, and the barometer falling rapidly. The conditions were generally favorable for the development of tornadoes. The storm appeared at Little Rock about 11:30 p. m. of the 22d in the form of a heavy thunderstorm, although the wind was comparatively light. Moving northeastward, it first assumed the proportions of a tornado at McCreanor, Lonoke County, about 2 a. m. of the 23d, where the damage was about $500 in property and 1 person was injured. About 8 miles southeast of Hickory Plains, Prairie County, the storm caused a loss of $5,000, killed 1 person, and injured 20. The storm passed southeast of Augusta, Woodruff County, about 3

a. m., killing 5 persons and injuring probably 30. The damage to property was estimated at $30,000. Continuing northeastward, the storm seemed to increase in severity in the vicinity of McCrory, Woodruff County, where trees were uprooted and houses blown down and scattered in various directions. In one neighborhood, 5 miles north of McCrory, 23 houses were destroyed and others badly damaged. Twenty-three persons were injured, but no lives were lost. About 5 miles southeast of Eightmile, in the southeastern part of Jackson County, there was a loss of about $3,000 on property. No one was killed in that vicinity, but 3 persons were injured. Farther northeast the destruction was very great, the little town of Fisher, in the southwestern part of Poinsett County, being almost entirely destroyed. Three people were killed at Fisher and about 28 injured, while the loss on buildings, live stock, and farm implements was estimated at $40,000. Northeast of Fisher, in the vicinity of Waldenburg, Poinsett County, 1 building was destroyed and a number of others damaged. The entire loss was estimated at $4,800. Two persons were reported injured, but no one was killed.

The rainfall was heavy throughout the entire section of country traversed by the storm, and the electrical display was very brilliant. A number of buildings were struck by lightning, but the loss by fire was not great on account of the heavy rain which attended the storm.

The path of the storm varied greatly in width in different portions of its course. At some places it was about 60 yards wide, while in other localities it was estimated to be nearly a mile in width. Reports indicate that the greatest damage occurred in Poinsett and Woodruff counties, and it is thought by some to have been the most destructive storm that ever visited Woodruff County.—*H. F. A. and T. R. T.*

[Extract from the Monthly Climatological Report, Arkansas Section, April, 1909.]

March, 1909.

On the afternoon and evening of March 8, 1909, tornadoes occurred over an area about 125 miles long by 10 to 60 miles wide, including parts of Ouachita, Cleveland, Dallas, Hot Spring, Grant, Saline, Jefferson, Pulaski, Lonoke, Prairie, and Monroe counties, the earliest storm occurring in Dallas and Hot Spring counties between 5 and 5:10 p. m., and the latest, which proved to be the most destructive, at Brinkley, Monroe County, about 7:10 p. m. These storms killed 64 persons, injured 671 others, and caused a property destruction aggregating about $635,000.

The low within which the tornadoes developed was central near Del Rio, Tex., at 7 a. m., Central time, with a pressure of 29.44 inches, and extended northeastward to the lower Mississipp Valley. During the following 24 hours it moved in a northeasterly direction across Texas, Louisiana, Arkansas, and Missouri (the storm center passing west of Little Rock, Ark., about 5:30 p. m. of the 8th—pressure 29.39 inches), and reached northeastern Missouri by 7 a. m. of the 9th.

The morning of the 8th was cloudy, damp, and abnormally warm in Arkansas, with south to east winds and a low and rapidly falling barometer. At Little Rock, in the center of the State, the temperature was 54° (12 degrees above normal), humidity 94 per cent, and reduced pressure, 29.70 inches. At 7 p. m. the temperature was 66° (14 degrees above normal), humidity 89 per cent, and pressure 29.42 inches. Heavy rains fell over the greater part of the State during the 24 hours ending with 7 a. m. of the 9th. The low was followed by a cool wave. At 7 a. m. of the 9th it was snowing at Bentonville, Ark., and the temperature had dropped to 34°, a fall of 20 degrees in 24 hours.

Most of the tornado reports received indicate that the direction was from southwest to northeast [See fig. 1] and that the path of great destruction varied from 100 yards to one-half mile in width. The pendant, funnel-shaped cloud which characterizes tornadoes was observed in many places. Pine Bluff, Ark., experienced a heavy hailstorm on the 8th, but no destructive winds.

FIG. 1.—Tornadoes in Arkansas, March 8, 1909.

The names of the towns and counties visited by the tornadoes, together with the number of people killed or injured and the approximate value of the property destroyed, so far as known, are given in Table 1, and the localities are shown in fig. 1.

TABLE 1.—*Losses and casualties by tornadoes in Arkansas, March 8, 1909.*

Place.	County.	Injured.	Killed.	Damage.
Staves	Cleveland.	8		$6,000 to $8,000
Brooks	Grant.			
Sheridan	Grant.		1	
Salem	Fulton.		1[a]	
Princeton	Dallas.			2,000
Eastward (near)	Jefferson.	5		1,500
Piney Woods	Jefferson.	3	1	
Baldwin's Switch	Jefferson.		1	
Ferda	Jefferson.		1	
Witherspoon	Hot Spring.	2		2,000
Malvern	Hot Spring.			9,750
Gifford	Hot Spring.			5,000
Perla	Hot Spring.			1,000
Fourche Dam (Little Rock)	Pulaski.	1	5	900
Galloway	Pulaski.	2		
Brinkley	Monroe.	600	49	600,000
Benton (near)	Saline.	3	1	
Hazen	Prairie.	20	4	5,000

[a] Died of fright.

The following extracts from reports of cooperative observers are interesting:

Princeton: The storm cloud looked like a ball of black smoke.

Staves: There were two storm clouds, one at 6 p. m. and another about thirty minutes later, both moving in the same direction. The first did the greater damage.

England, Lonoke County: I watched the clouds for about an hour before the storm reached England, as I had read the Weather Bureau map at 5 p. m., and was expecting a severe storm. I did not see any funnel-shaped cloud, but that may have been due to the fact that the clouds were low and it was rather dark. About ten minutes before the storm there was much lightning in the west, southwest, and south, and the clouds were going north. At about the same time the clouds changed to northeast, and ten minutes later had passed away. The high wind did not last more than two or three minutes. While the wind was blowing the roar was like that made by many freight cars going at a great speed. Large trees were uprooted and carried a great distance away, the trees in the storm's path having been twisted off about 10 or 15 feet above the ground.—Dr. J. C. Chenault.

Brinkley: The tornado struck this place about 7:10 p. m., central time, and crossed the city from southwest to northeast. It was preceded by vivid lightning and a hard rain, and did not last more than five minutes. The path of greatest destruction extended from a point about 5 miles southwest to a point about 10 miles northeast of the town. About 260 residences and 600 other buildings were totally destroyed, and 750 dwellings and 1,200 other buildings were partially destroyed. The total losses amounted to $600,000, of which five-sixths were in buildings. Many buildings rocked preceptibly before crashing to the ground. The destruction of the electric-lighting plant threw the city into darkness. Fires started at many points, and only the heavy downpour of rain that followed prevented a general conflagration. In several instances all the members of a family were killed. A number of cars were blown from the tracks of the Rock Island Railroad at Brinkley and Kerr.

April, 1909.

Tornadoes occurred in Monroe and Woodruff counties on the 6th. One person was injured, and the losses in buildings and merchandise were about $5,000.

On the 29th tornadoes occurred in nine northern and three southern counties, killing 17 people, injuring 76 others, and causing property destruction aggregating about $100,000.—*H. F. Alciatore.*

RED SNOW IN MICHIGAN.

By A. WIESNER. Dated: Houghton, Mich., April 13, 1909.

Late Saturday night or early Sunday morning Calumet was visited by a peculiar storm in that from the air fell a reddish brown sand, mixed with snow, the storm lasting probably the greater part of a half hour. The wind as near as could be judged because of its irregular velocity and variations came from an easterly to southeasterly direction. The sand was fine and light. It has been learned that this sand fell Saturday night and Sunday morning all over the upper peninsula. As far as can be learned no one has advanced an explanation of the phenomenon.

Explorers in the Arctic regions have told of falls of "red" snow similar[1] to that which visited Calumet Saturday night. Often at sea ships are covered with a like substance, which falls from the heavens, although the ship be many miles from land. It is supposed the high wind carried the sand a great distance from some point where the earth was bare of snow and was dry.

With reference to the above extract from the Mining Gazette of Houghton, Mich., for April 13, 1909, I would add that this phenomenon was particularly noticeable at Lake Linden and Calumet, 10 to 12 miles north of Houghton. Fine traces of this dust, resembling powdered brick or hematite dust, were also noticeable in Houghton on the station psychrometer and on the upper surface of the thermograph. The wind during the night of this occurrence, April 10–11, 1909, was brisk east to southeast, the weather was damp, and most of the ground in this locality was still covered with snow. It is evident, therefore, that the dust was not of local origin.

[1] The "red snow" of the polar regions usually owes its color to the rapid increase of a microscopic red fungus-like plant, and rarely to a mineral coloring matter, as in the present case. See Monthly Weather Review, 1901, 29; 465, and elsewhere.—*C. A., jr.*

THE AURORA OF MAY 15–16, 1909.

The captain of the Hamburg-American steamer *Pallanza* sends the following very interesting report to the Marine Division of the Weather Bureau.

[TRANSLATION.]

NEW YORK, N. Y., *May 17, 1909.*

To the DEUTSCHE SEEWARTE,
HAMBURG, GERMANY.

On the night of May 14–15, 1909, as the steamship *Pallanza*, en route to New York, was in longitude 62° to 64° west, a bright aurora was observed.

The next night, May 15–16, as we were nearing the Nantucket Shoals lightship another and very singular display was observed. The night was calm and very clear, the stars visible almost to the horizon, when from about 10 p. m. to midnight I observed two brilliant spots of pure white light in the northwest and northeast, respectively. These spots had the outline of a candle flame and their intensity varied from that of mild moonlight to a light so strong that it was almost possible to read by it on the bridge. In the brighter intervals fascicles of rays shot from each spot to the zenith, where, from time to time both spots were united in a great arc of light intersecting the Milky Way at an angle of 20°. Stars of the higher magnitudes were distinctly recognizable through the aurora itself.

Both spots appeared to have sharply defined bases at an altitude of about 40°, sending vertical streamers toward the zenith only. No luminous phenomena were visible from the bases of the brilliant spots down to the horizon. At the same time very frequent heat lightning was observed in the west.

At 2:45 a. m. we passed the Nantucket Shoals lightship at a speed of 11 miles per hour. In the mean time—about 1 a. m.—the aurora in the northwest had disappeared and the one in the northeast had shifted slowly to about due east, where it remained visible until daybreak. The heat lightning in the west had continued uninterruptedly.

At 7:20 a. m., May 16, the ship ran into a bank of fog, whereupon the compass immediately began to oscillate and show perceptible electrical disturbances. Repeated observations showed a sudden increase in the easterly deviation amounting to about 1.5°. Accurate determinations of this increase were not practicable on account of the oscillations of the compass card, which swung 15° to 22° to either side. When the fog disappeared about 10 a. m. this magnetic disturbance disappeared also.

I believe I am not in error when I assume a causal connection between the above described phenomena.

Very respectfully,

(Signed) R. NISS, *Captain.*

We reprint the following observation[1] of the same aurora as seen from Blue Hill Observatory, Mass., in latitude 42° 13′ N., longitude 71° 07′ W., altitude 105 meters.

BLUE HILL OBSERVATORY, *May 17, 1909.*

One of the brightest auroras seen in recent years at Blue Hill Observatory was visible for several hours on the evening of May 15 last. When first observed, at 8:58 p. m., it formed three detached luminous patches, the two brightest having been near the zenith. At 9:10 p. m. the latter two merged to form one large bluish-gray mass, of unusual brightness. After that, the luminosity changed rapidly from moment to moment, while the form was altered but slightly, the whole mass moving slowly to the south and west. For about three quarters of an hour the main mass took the shape of a long-handled dipper, the bowl appearing like the head, and the handle like the tail of a huge comet, which many people thought the phenomenon to be. At 10:36 p. m. it was seen as five detached areas of light, which, after about ten minutes, joined to form an unbroken arch which reached from west to east almost entirely across the sky, the highest point passing slightly to the south of the zenith. After 11 o'clock the arch broke up into separate masses which changed in brilliancy from time to time, but gradually faded until all had disappeared by 11:30 p. m. In the two hours from 8:59 p. m. to 10.59 p. m. the mass moved as a whole about 25° toward the south and about 50° toward the west, as measured from a point near the center of the main mass which was originally about 5° to the north of the zenith. After 10 o'clock we had the unusual condition of the "northern lights" entirely to the south of a west-to-east line through the zenith. It is also worthy of note that the southern border was at all times a distinct and clean-cut line, while the northern border was everywhere indefinite, gradually dying out at about 30° to the north of the zenith. During the course of the evening the luminous area varied in width from 10° to about 35°.

The aurora was remarkable on account of its unusual position, its rapid changes in brilliancy, and its varying shape. The color was a pale bluish-gray, no iridescence having been seen at any time. Moreover, there was no suggestion of streamers or rapidly-moving iridescent patches, often referred to as "merry dancers." When the aurora was

[1] See Science, 1909, 30 (N.S.):57.

at its maximum brilliancy only the stars of brightest magnitude could be seen in that region of the sky, and the "milky way" was rendered entirely invisible. Over nine-tenths of the sky was cloudless throughout the evening, a trace of alto-stratus having been visible above the northern horizon, and an equal amount of cumulo-nimbus with distant lightning having been seen far off to the west. ANDREW H. PALMER.

Captain Niss in his description remarks that at 7:20 a. m. of May 16 his ship ran into a bank of fog and that coincidently his compass began to oscillate, swinging 15° to 22° to either side of an easterly deviation which was 1.5° greater than that normal for the year and place. This oscillation and increased deviation both ceased when he ran out of the fog, and his last sentence might give the impression that he ascribes the compass disturbance to the presence of the fog, but this is not at all likely.

One may, however, explain this sudden compass deviation in two ways. (1) It may have been the expression of the highly charged lower atmospheric strata which must have accompanied the well-marked thunderstorms to the west reported by both observers. In this case the needle disturbances would have been characteristically sharp jumps from the normal position, occurring at the times of the discharges. (2) It may have been due to the continued auroral phenomena, become invisible in the light of dawn. In this case the needle would have oscillated more or less strongly swinging to either side of the normal deviation, if there were such vibrations as produce the the "merry dancers"; or would have remained more steady, perhaps at an abnormal point if the aurora were in the nature of a glow. Captain Niss' report is not quite explicit enough to permit us to choose between these explanations.—*C. A., jr.*

AN ANNOTATED BIBLIOGRAPHY OF EVAPORATION.

By MRS. GRACE J. LIVINGSTON. Dated Washington, D. C., January 8, 1908.

[*Continued from the Monthly Weather Review, March, 1909.*]

1889—*Continued.*

Grossmann. [L.]
Beiträge zur Geschichte und Theorie des Psychrometers. Met. Zeits., 1889, **6**:121–30, 164–76.

Discusses the history and theory of the psychrometer.

Seyfert, T.
Der Einfluss des Bedeckens und des Mischens der Moorboden mit Sand auf seine Verdunstungs- und Temperaturverhältnisse. Mitt. z. Förderung der Moorkultur, 1889, Nos. 17, 18: 205–23; Centbl. Agr. Chem., 1889, (—):678–80. Abstract in Forsch. Geb. Agr. Phys., 1880, **13**:63–4.

Experiments in evaporation from natural moor soil, from the same with sand mixed into the surface layer, and from the same with sand on top but not mixed in, for the period June to October, gave amounts in the proportion, 100:38:20. The effect of a surface layer of sand in retarding evaporation is clearly shown.

Symon, G. J.
On the amount of evaporation. Brit. rainf., 1889, (—):18–43.

A complete résumé of all previous reports of evaporation published in "British Rainfall" from 1867 to 1887, together with descriptions and drawings of the various instruments used at Strathfield Turgiss. Tables of daily evaporation at Camden Square from July, 1889 to June, 1890, and the totals and maxima for each month and year from 1885–1890 are given.

Tacchini, P.
Temperatura ed evaporazione a Massaua. Atti r. accad. Lincei, 1889, **5** (4):329–30.

Investigations show that evaporation at Massaua is almost twice that at places whose mean temperatures are but half as high.

Place.	Mean annual temperature.	Mean daily evaporation.
	°C.	*Mm.*
Bari	15.7	3.1
Massaua	29.8	7.3
Reggio (Calabria)	17.6	3.6

Voeikov.
See Woeikof.

Waldo, Frank.
Distribution of wind velocities in the United States. Amer. met. jour., 1889, **6**:309–10.

Discusses the relation between the distribution of wind velocities and evaporation. Describes Russell's (1886, 1888) experiments in this line.

Woeikof, Alexander.
Der Einfluss einer Schneedecke auf Boden, Klima, und Wetter. Geog. Abh., 1889, **3** (Hft. 3):99.

Although the air above a large extent of snow is usually saturated owing to the continual evaporation from the snow, certain winds are so dry that the evaporation can not always maintain this saturated condition of the air. A greater dryness in the air above snow may also result in decreased evaporation due to the lower temperature of the snow compared that of the air.

1890.

Abbe, Cleveland.
Preparatory studies for deductive methods in storm and weather predictions. Ann. Rpt. Chief Signal Officer for 1889. Washington. 1890. App. 15, p. 117–21.

Discusses the various factors influencing the rate of evaporation. For meteorological purposes evaporation from a free water surface, or preferably from moistened cloth or paper, as in the ordinary psychrometer or in the Piche atmometer, is considered a sufficient indication of the evaporating power of the air. Presents the conclusions reached by Tate; the formulas derived by Wellenmann, Stelling, and Fitzgerald; and Russell's comparisons of evaporation with changes in wind velocity.

Battelli, Angelo.
Sull' evaporation dell' acqua e del terreno umido. Nuovo cimento, 1890, **28**(3):247–56. Abstract in Naturw. Runds., 1891, **6**:270; Ann. uffic. cent. met. Ital., **9**:—; Met. Zeits., 1891, **8**:394.

Comparative measurements of evaporation, both in sun and shade, from a free water surface and from soil saturated with water, at Chieri (Turin). Also observed a Piche atmometer, a psychrometer, and an anemometer. (See Battelli, 1892.)

Brückner, Eduard.
Verdunstung einer Schneedecke. Met. Zeits., 1890, **7**:150–2.

Review of Voeikov, 1889 and 1890. According to Brückner condensation ordinarily occurs on snow, rather than evaporation from it.

Colin, R. P. E.
Observations météorologiques faites à Tananarive. Obs. roy. de Madagascar. Tananarive. 1890. 2 vols. 8vo. Review in Symons's met. mag., 1892, **27**:38–40.

His evaporator consists of a zinc tank, 40×40×2.5 inches, inclosed in a wooden box. A table gives the evaporation for the first ten days in February, 1890.

Ekholm, Nils.
Zur Frage über die Verdunstung einer Schneelage. Met. Zeits., 1890, **7**:224–6. Notice in Forsch. Geb. Agr. Phys., 1890, **13**:475.

Discusses the question raised by Voeikov (1890), who declared that snow will evaporate when the temperature of the air is below zero.

Houdaille, F.
Mesure de l'évaporation diurne; description d'un évaporomètre enregistreur. Bul. mét. Hérault, 1890. See Houdaille, 1892.

Conclusions: (1) Daily evaporation as measured by the Piche atmometer is very irregular as compared with that from an evaporating surface more naturally exposed to the action of the wind and nearer the temperature of the air. (2) A continuous record of the rate of evaporation is important for meteorology and for various industries. (3) Describes a recording "evaporometer," which employs the registering mechanism of the Richard thermograph. (4) This rate is always much higher in the daytime than at night, generally at least three times higher. (5) The maxima are determined by the predominance of one of the three factors, temperature, relative humidity, and wind velocity.

Specifies objections to the Piche atmometer. Describes his own atmometer, which consists of an evaporating surface of blotting paper clamped on a brass plate connected with a graduated Mariotte's tube. An opening, 2 mm. in diameter, in the brass plate allows the liquid supplied from the tube to keep the paper constantly soaked.

Moulan, T.-C.
Quantités d'eau évaporées ou absorbées par la végétation dans la bassin de la Gileppe. Ciel et terre, 1890, **11**:328.

Approximate estimate of the water absorbed or evaporated by vegetation.

Russell, Thomas.
Evaporation. Mo. Weather Rev., 1890, **18**:290.

Table 1 shows the depth of monthly evaporation for 1888–9, as measured in a pan and by a Piche atmometer, at Sweetwater Dam, San Diego County, Cal. Table 2 shows the depths of evaporation observed at a number of stations in 1888–90 with Piche atmometers. Tables 3 and 4 show the depths evaporated from pans at stations other than those where the Piche had been used.

Symons, G. J.
On the amount of evaporation. Brit. rainf., 1890, (—):17–31.

Deals in detail with the work of Dines, 1870; Evans at Nash Mills, Hertfordshire (see Greaves, 1876); Greaves, 1876; Lawes at Rothamsted; S. H. Miller at Wisbech, 1878; Peek at Rousdon Observatory, near Lyme Regis, Devon; and Russell at Sydney, N. S. W. Symons assumes that at Sydney a facsimile of the Strathfield Turgiss tanks would lose about 30 inches a year.

van Bebber, W. J.
Lehrbuch der Meteorologie. Stuttgart. 1890. p. 103–9.

General discussion of the process of evaporation, with a description of the Piche atmometer. Results of Eser, Ebermayer, and Stelling are reviewed.

Woeikof, A.
Verdunstung einer Schneelage. Met. Zeits., 1890, **7**:38–9.

Points out that evaporation will take place from the surface of snow as long as the air temperature is below zero. (See Brückner, 1890.)

Wollny, E.
Forstlich-meteorologische Beobachtungen. (Zweite Mitteilung.) Forsch. Geb. Agr. Phys., 1890, **13**:134–84.

Continued from 1887. (See Wollny, 1895, for summary.)

1891.

Allen, H. N.
See Brace, de W. B., and H. N. Allen.

Brace, de W. B., and H. N. Allen.
Meteorological observations for 1890. Nebr. exp. sta. bul., 1891, 4 (no. 27):33–72; Exp. sta. rec., 1891, 3:29.

Gives the results of observations with 6 Piche evaporometers from June to October, suspended at elevations of 22, 40, 60, 80, and 100 feet.

[Bartet.]
Influence de la futaie de hêtre sur les pluies, l'évaporation et la température de l'air. Ciel et terre, 1891–2, 12:313–9.

Quotes observations near Nancy by Mathieu in 1867–77. In discussing the influence of a beech forest on rainfall, evaporation, and temperature at Bellefontaine from 1878–88 Bartet found the following data:

	In woods.	In open.
Annual evaporation (millimeters)	146.4	472.1
Annual rainfall (millimeters)	722.8	852.2
Evaporation as per cent of rain	20%	55%
Ratio of evaporation	1	3.22

The general results at Nancy and Bellefontaine are in mutual accord.

De Heen, P.
Recherches sur la vitesse d'évaporation des liquides pris au-dessous de la température d'ébuillition. Bul. acad. sci. de Belgique, 1891, 21(3):11–25, 214–9, 798–810. Review in Ciel et terre, 1891. 12: 49–51. Abstract, Met. Zeits., 1891, 8:351.

Concludes (1) The rate of evaporation increases at first rapidly with the wind velocity, but with higher velocities the increase is more gradual. (2) For any wind velocity evaporation is directly proportional to the vapor pressure. (3) Evaporation is proportional to the molecular weight × vapor pressure.

Further experiments show that a current of saturated air is capable of raising molecules from the surface of the water. A formula is derived for expressing the rate of evaporation: $v = A F (109 - 0.88 + V^{\frac{1}{2}})$ where A = a constant, F = the vapor pressure at the temperature of the liquid, and V = wind velocity. Observes that all evaporometers acting by imbibition must furnish too small results since the soaked surface is cooled by the evaporation. This influence is barely perceptible at the free surface of a liquid, as convection tends to counteract it.

Greeley, A. W.
Irrigation and water storage in the arid regions. (A report on the climatology of the arid regions of the United States with reference to irrigation.) 51st Cong., 2d Sess., House of Rep., Ex. Doc. No. 287. Washington. 1891.

A compilation of data on rainfall and evaporation in the various arid regions of the world, with particular reference to the extensive arid regions of the United States. Appendices contain curves of precipitation, evaporation, amount of sunshine, and normal temperature and weight of aqueous vapor, also tables and charts for Colorado, New Mexico, Arizona, Utah, Nevada, and California. "These curves are composite ones, made up from selected stations, and therefore fairly represent evaporation conditions over the States or sections to which they pertain."

Hann, J.
Beobachtungen über Verdunstung zu Strathfield Turgiss, 1870–1883. Met. Zeits., 1891, 8:118–9.

Describes methods of observing evaporation at Strathfield Turgiss and Camden Square, London, England, and compares the results with the evaporation measured by Tacchini in southern France and by de Lesseps at the Suez Canal.

[Royal Meteorological Society.]
Exhibition of rain and evaporation gages. Amer. met. jour., 1891, 7:561-2.

The evaporation gages shown at the Royal Meteorological Society's 12th Annual Exhibition of Instruments included several instruments employed for measuring the evaporation from a free surface of water, and others for use with growing plants.

Symons, G. J., John W. Tripe, and William Marriott.
Twelfth Annual Exhibition of Instruments by the Royal Meteorological Society, held March 3–19, 1891. Quart. jour. roy. met. soc., 1891, 17:180–92.

Describes most of the instruments exhibited, notably the evaporometers designed by Babington, Lamont, Wild, de la Rue, Piche, Richard, and a collection of instruments exhibited by Symons. An evaporometer designed for use with growing plants is also described (p. 187, ¶ 59.)

Symons, G. J.
On the evaporation from a water surface at Camden Square, London. Brit. rainf., 1891, (—):24–5.

Gives tables of the daily evaporation from the standard tank from July, 1891, to June, 1892; also tables of the monthly and annual totals and maxima for 1885 to 1892.

Ule, Willi.
Zur Beurtheilung der Evaporationskraft eines Klimas. Met. Zeits., 1891, 8:91–6.

Investigations with a Wild evaporometer lead to a formula employing the psychrometer differences and the wind velocity, viz: $v = A \Sigma (t - t') w$, where v = the rate of evaporation, A = a constant, t and t' = the psychrometer temperatures. The value of A varies considerably with the season.

1892.

Battelli, Angelo.
Comparison de l'évaporation d'une surface d'eau et d'une surface de terre humide. Abstract in L'atmosphère, Octobre, 1892, (—):145–148; Ciel et terre, 1892–3, 13:436.

From the experiments detailed in Batelli, 1890, he concludes: When the temperature of the air is rising, evaporation from saturated soil is in general, greater than from a surface of still water; when the temperature is decreasing, evaporation from the soil diminishes more rapidly than that from water. The evaporation from a free water surface increases more rapidly with the velocity of the wind than that from moist soil. The higher the relative humidity the greater is the proportion of water evaporated from saturated soil in comparison to that evaporated from still water. Evaporation from water in the sun is greater than that in the shade, not only during the day but also during the following night.

Brace, de W. B.
Mean relative evaporation at six different elevations. Nebraska exp. sta. bul., 1892, No. 20: 215–51. Abstract in Exp. sta. rec., 1892, 3:799.

Increase in evaporation is shown with increase in altitude. Continuation of his experiments of 1891.

Carpenter, L. G.
Irrigation engineering. Colorado exp. sta., ann. rpt., 1891:45–57. 1892. Abstract in Exp. sta. rec., 1892, 4:368–9.

A table shows comparative rates of evaporation from water in tanks placed in the ground at Fort Collins, Divide, and Rockyford, Colo., and from tanks floating in a canal and a lake

King, F. H.
Investigations relating to soil moisture. Wisconsin exp. sta., ann. rpt., 1891:100–34. Abstract in Exp. sta. rec., 1892, 4:122–9.

Experiments show that spring plowing checks the evaporation of soil water. The mean daily rate of evaporation from cultivated soil was 0.665 lbs., and from uncultivated soil 0.808 lbs. per sq. foot.

Houdaille, F.
Marche diurne de l'évaporation à Montpellier, 1891–2. Bul. mét. Hérault, 1892, (—):59–78. Review in Met. Zeits., 1893, 10:431–2.

The curve of a self-recording evaporometer running for 469 days, during the years 1891–2, shows three distinct periods, from midnight to sunrise, from sunrise to sunset, and from sunset to midnight. These periods correspond to equally distinct periods in the rate of evaporation from soil and from plants. The maxima and minima for these periods show interesting variations. The average ratio between daily and nocturnal evaporation is 3.82, varying from 6.90 in August to 1.63 in December. Gives a résumé of the experiments by Hépites, 1887. Diagrams compare evaporation with relative humidity, temperature, and wind velocity.

Houdaille, F.
Recherches expérimentales sur l'influence de la vitesse du vent, de la radiation solaire, et de l'état électrique de l'air dans le phénomène de l'évaporation. Ann. école nat. agr., Montpellier, 1892, 6:197–247.

An investigation of the influence of the velocity of the wind upon evaporation disclosed the following facts: (1) The increase in the rate of evaporation with air movement is very rapid for low velocities, but at 4 meters per second and higher it becomes almost proportional to the wind velocity. (2) The increase of the rate of evaporation is proportional to the increase in wind velocity independently of the difference $(F-f)$, the difference between the vapor tension at the surface of the liquid and that of the air. (3) The relation of the evaporation from a surface of 13 sq. cm. to the air current and to $(F-f)$ is given by the formula,

$$P = 1.475 (F-f) + 0.725 [(F-f)^2 + 10 (F-f)]^{\frac{1}{2}} . [V^2 + 17 V]^{\frac{1}{2}}.$$

(4) When, under the action of the wind, the evaporating surface cools considerably, the rate of evaporation should rather be compared to the factor $(F'-f)$, in which F' is the vapor pressure at the temperature t' of the wet-bulb. (5) The ratio between the rates of evaporation from different surfaces remains almost constant and independent of the wind velocity.

A study of the influence of solar radiation showed (1) that the increase of evaporation due to solar radiation is almost proportional to the intensity of the latter whatever may be the initial value of the evaporation, as measured in shade and in quiet air. (2) The coefficient of the utilization of solar heat in vaporization varies between very wide limits according to the temperature, humidity of the air, and the intensity of insolation. (3) A high electric tension causes a rather rapid increase in the rate of evaporation.

Houdaille, F.
Recherches expérimentales sur le phénomène de l'évaporation. L'atmosphère, August, 1892, (—):101–5.

Latham, Baldwin.
Presidential Address to the Royal Meteorological Society. Quart. jour. roy. met. soc., 1892, 18:53–67. Abstract in Symons's met. mag., 1892, 29:10–11.

Discusses the laws and conditions governing evaporation. Describes experiments showing the influence of capillary action in increasing the evaporating surface, and thus the amount of evaporation. A diagram compares evaporation, differences in vapor pressure, temperatures of air, water, and dew-point. Latham's evaporometer forms the frontispiece to Brit. rainf., 1897.

Müller, P. A.
Ueber die Frage der Verdunstung der Schneedecke. St. Petersburg. 1892. 47p. 4to. From Repert. f. Met., 14: No. 4. Abstract in Ciel et terre, 1893, 14:192; Met. Zeits., 1892, 9:(80).

In 27 per cent of the hourly observations condensation took place at the surface of the snow, while evaporation occurred in the remaining 73 per cent.

Paris, Observatoire de la Tour Saint Jacques.
Monthly meteorological tables for 1892. L'atmosphère, 1892.

These tables include daily observations of a Piche evaporometer and of a self-recording instrument.

Schubert, J.
Das Klima von Eberswalde nach 15-jährigen Beobachtungen, 1876–1890. Met. Zeits., 1892, 9:233–5.

The average monthly evaporation varies from 7.5 mm. in December to 62.4 mm. in June The annual average is 405.5 mm.

Symons, G. J.
Evaporation. Brit. rainf., 1902, (—):15–23.

Evaporation results are quoted from the Massachusetts State Board of Health Report on Water Supply and Sewage for 1890. Compares the evaporation at Lawrence, Mass., with that at Philadelphia, Pa., at Otterbourne, Hants, at Strathfield Turgiss, and Camden Square, London, Eng.

1893.

Hann, J.
Houdaille's Untersuchungen über den täglichen Gang der Verdunstung zu Montpellier. Met. Zeits., 1893, 10:431-2.

Review of Houdaille, 1892, 1st title.

Hubbard, Gardiner G.
Relations of air and water to temperature and life. Nat. geog. mag., 1893, 5:112–4.

Scattered facts concerning evaporation are cited.

Kerner, Fritz von.
Korrespondirende Berggipfel and Thalbeobachtungen der Temperatur, Feuchtigkeit und Verdunstung. Met. Zeits., 1898, 10:269.

An increase in the amount of evaporation from 0.6 millimeter at 1,215 meters altitude, to 0.9 millimeters at 3,274 meters, is attributed to the decrease in the air pressure since there was no wind.

Piche, A.
Le déperditomètre. Paris. 1893. 4 p. 8vo. From Compt. rend. assoc. franç., Congrès de Pau, 1892.

Diagram and description of an instrument to indicate "sensible temperatures."

Symons, G. J.
Experiments on evaporation at Southampton Waterworks, and at Camden Square. Brit. rainf., 1893, (—):23–6.

Presents the usual records for the large tanks.

van Bebber, W. J.
Meteorologie. Leipsic. 1893.

A general survey on p. 133–5 of the existing knowledge regarding evaporation from water and soil surfaces, and from plants.

Waldo, Frank.
Modern Meteorology. London. 1893. 8vo. p. 149–53, 205–7, 438–40.

Discusses the best methods for investigating evaporation; describes the Piche and Wild evaporometers, and gives numerous statistics of evaporation from water, soils, plants, etc. Discusses the influences of light and temperature and summarizes Wollny's experiments in soil moisture and evaporation.

1894.

Abbe, Cleveland.
Humidity. Mo. weather rev., 1894, 22:407, 453, 496.

Fitzgerald's (1886) formula for determining average vapor pressure is presented. The evaporometer is spoken of as an "integratimg hygrometer."

Britzke, O.
Ueber den jährlichen Gang der Verdunstung in Russland. St. Petersburg. 1894. 54 p. 4to. Repert. f. Met., 17, No. 10. Review Met. Zeits., 1895, 12:(76)–(77).

Tables of temperatures, relative humidity, wind velocity, evaporation and the relation between the rainfall and evaporation. The observations have considerable value, according to Kassner, owing to the fact that they were made at so many different stations with similar apparatus, the Wild weighing evaporometer similarly exposed in a Wild thermometer shelter, and for long periods of time.

King, F. H.
Studies relating to ground water and soil moisture. Wisconsin exp. sta. rpt. for 1893, p. 167–200. 1894. Abstract in Exp. sta. rec., 1896, 7:565–7.

It is stated that annual evaporation from manured soil exceeded that from unmanured by 108.5 tons per acre. In two experiments with tubes of sand, one wet with distilled water, the other with a solution of potassium nitrate, capillary ascent and evaporation from the surface was shown to be 22.84 per cent greater in the presence of the potassium nitrate.

Moore, John William.
Meteorology. London. 1894. p. 181–5.

Various methods of observing evaporation are described.

Ruvarac.
Ergebnisse der ombrometrischen Beobachtungen in Böhmen für 1893. Technisches Bureau des Landesculturrathes. Prag. 1894.

See Ruvarac, 1895, and Richter, 1895, for results.

Symons, G. J., and H. Sowerby Wallis.
Experiments on evaporation at Southampton Waterworks, (Otterbourne, Hants), and at Camden Square. Brit. rainf., 1894, (—): 21–4.

The two similar tanks show an annual rate of 19.5 inches at Otterbourne, and 14.5 inches at Camden Square, London.

Todd, Charles.
Meteorological work in Australia, a review. n. p. 1894. 25 p. 8vo. (Reprinted from Rpt. Australasian assoc. adv. sci., 1893.) Summary in Symons's met. mag., 1895, 30:44–5; Met. Zeits., 1895, 12:36–7.

Gives table of mean evaporation at Adelaide for 23 years, and at Alice Springs for 1890–2. The annual average at Adelaide is 55.53 inches; at Alice Springs, 98.55 inches in 1891, and 100.35 inches in 1892. The average rainfall at Adelaide for 54 years is 21.08 inches; at Alice Springs for 19 years, 11.25 inches. (See Todd, Chas., 1879.)

Tomlinson, S.
Rainfall and evaporation observations at the Bombay Waterworks. Quart. jour. roy. met. soc., 1894, 20:63–70.

Gives temperature, relative humidity, rainfall, etc., at Colaba Observatory, the evaporation at the Bhandarwada Filters and elsewhere. Also the approximate average evaporation that may be expected monthly from a water surface in the neighborhood of Bombay, showing the highest rates in March, April, and May, and the lowest in July, August, and September. The annual total from a surface of 1 square foot is 85.5 inches, from a reservoir of 10,000 square feet, 76.0 inches, and from a lake of 300 to 3,000 acres, 62.3 inches.

Vermeule, C[ornelius] C[larkson].
Report on the water supply, water power, the flow of streams, and attendant phenomena. Final Rept., State Geologist of New Jersey, Vol. III. Trenton. 1894.

Formulas for evaporation are developed from the values of the annual rainfall and the mean annual temperature, but in most cases the computed values fail to agree with those obtained by observation. Abstracted by Rafter, 1903.

Wollny, E.
Forstlich-meteorologische Beobachtungen. Dritte Mitteilungen. Forsch. Geb. Agr. Phys., 1894, 17:153–202. Abstract Exp. sta. rec., 1894, (—):—; Met. Zeit., 1896, 13:76–7.

Describes experiments comparing the evaporation from pine trees, birch trees, grass and fallow land with the rainfall. The results of this and previous papers in 1887 and 1890, are summarized in Wollny, 1895. See also Abbe, 1895.

1895.

Abbe, Cleveland.
The meteorological work of the U. S. Signal Service, 1870 to 1891. Rpt. Internat. Meteorol. Cong., Chicago, August, 1893. U. S. Weather Bureau, Bul. 11, pt. II (Apr., 1895), p. 232–285.

Regular observations of evaporation were inaugurated by the Signal Service in 1885, and T. Russell's "investigation of the influence of the wind on the indications of Piche's apparatus and his estimates (Russell, 1888) of the general depth of evaporation throughout the United States, mark out the path that must be pursued by future investigators in this line."

Abbe, Cleveland.
Note by the Editor. Mo. weather rev., 1895, 23:421–2. Notice in Exp. sta. rec., 1897, 8:111. Reprinted, Nature, 1896, 54:283.

Translation of summary of Wollny's (1895) investigations on evaporation.

Bebber, W. J. van.
Hygienische Meteorologie. Stuttgart. 1895.

General discussion on p. 150–2 of the process of evaporation, the factors influencing it, and the Piche evaporometer as a suitable instrument for measuring its amount.

Harrington, Mark W.
Sensible temperatures. Paper read before the American Climatological Association in Washington, 1894. Review in Amer. met. jour., 1895, 12:93–4.

Points out that the sensible temperature is lowered by the absorption of heat due to evaporation.

Houdaille, F.
Météorologie agricole. Paris. 1895. p. 36–9, 103–4, 124–5.

This publication recounts the results of much of the author's previous work on evaporation, adding nothing new to the conclusions reached in preceding papers.

Krebs, Wilhelm.
Verdunstungsbeobachtungen mit dem Doppelthermometer. Met. Zeits., 1895, 12:38–9.

The discussion started in this paper regarding the psychrometer as a measure of evaporation, is dealt with at greater length in 1904.

Pague, B. S.
Sensible temperatures, or the effect of heat on the body in California. San Francisco. 1895. Reprinted, Amer. met. jour., 1895, 12:196–8.

Treats of the well-known fact that the body is cooled by the evaporation of perspiration from the skin.

Penck, Albrecht.
Evaporation in central Europe. Reviewed in Geog. jour., 1895, 5:583.

Direct measurements of evaporation in Austria and Bavaria since 1821 and in Prussia since 1876 indicate an average yearly evaporation in north Germany of 15.7 inches, decreasing southward to about 11.8 inches. A marked increase is shown in the Hungarian plain, 25.6 inches at Budapest and still more in the southeastern districts. An almost uniform decrease of 60 per cent is observed in forest stations, compared with the open country, while a remarkable increase is noticed in towns. In Vienna the evaporation exceeded that in the immediate neighborhood by 5.9 inches. Classifies the monthly curves of evaporation according to districts. The total aqueous vapor passing into the air over a large area is estimated from the total rainfall and the total calculated discharge by rivers, the difference being taken as the amount of evaporation. From these results he concludes that evaporation is influenced to some extent by the rainfall itself.

Russell, Thomas.
Meteorology, weather, and methods of forecasting. Descriptions of meteorological instruments and river flood predictions in the United States. New York. 1895. 8vo.

On p. 47 describes the Piche atmometer and an experiment showing the effect of various wind velocities on evaporation. On p. 70–1 compares the depth of water evaporated at various stations.

Symons, G. J., and H. Sowerby Wallis.
Percolation experiments at Apsley Mills, Hemel Hempstead. Brit. rainf., 1895, (—):26–35.

The results of percolation experiments at Apsley Mills, conducted by Sir John Evans, are tabulated, according to seasons, for the 12 years, 1883–94, as follows:

Rainfall, percolation, and evaporation at Apsley Mills, 1883–94.

	Rain.	Sand, 3 feet.		Sand, 5 feet 2 inches.	
		Percolation.	Evaporation.	Percolation.	Evaporation.
Summer	12.55	3.91	8.64	3.94	8.61
Winter	13.51	12.55	0.96	12.57	0.94
Year	26.06	16.46	9.60	16.51	9.55
		Chalk, 3 feet 3 inches.		Chalk, 5 feet 2 inches.	
Summer		1.83	10.72	1.97	10.58
Winter		10.42	3.09	15.25	3.26
Year		12.75	13.81	12.22	13.84

Rainfall, percolation, and evaporation at Apsley Mills, 1883–94—Cont'd.

	Ordinary soil, 3 feet 3 inches.		Ordinary soil, 5 feet 2 inches.	
	Percolation.	Evaporation.	Percolation.	Evaporation.
Summer	1.54	10.01	1.59	10.96
Winter	11.21	3.30	10.97	2.54
Year	12.75	13.31	12.56	13.50

Symons, G. J., and H. Sowerby Wallis.
Experiments at Southampton Waterworks and at Camden Square. Brit. rainf., 1895, (—):36–9.

Evaporation observations at Camden Square from 1885 to 1895 and at Otterbourne from 1892 to 1895 show an annual average for the former place of 14.66 inches, and 20.46 inches for the latter.

Wallis, H. Sowerby.
See Symons and Wallis.

Woliny, E.
Untersuchungen über die Verdunstung. Forsch. Geb. Agr. Phys., 1895, **18**:486–516. Review in Met. Zeits., 1896, **13**:362–4; by Abbe, 1895; Ciel et terre, 1896, **17**:570–1; Centbl. Agr. Chem. (Biedermann), 1897, **26**:74–7.

"Lysimeters" (zinc boxes 400 square centimeters in cross section and 30 centimeters deep), standing in the open with a 15-centimeter layer of soil in them, and weighed every five to nine days, furnished the following results: (1) Soil evaporates less than a free water surface. (2) Sand evaporates least, loam most, while bare turf and humus or vegetable mold are intermediate. (3) Evaporation from soil is increased by a cover of vegetation. (4) Evaporation depends on meteorological conditions and on the quantity of moisture in the soil. (5 and 6) Temperature is the most important factor affecting evaporation, modified by other factors, mainly by the amount of water supplied by the substratum. (7) For evaporation from a free water surface, from saturated soil and from ordinary moist soil whether covered with living plants or not, the important elements to be considered are temperature, relative humidity, cloudiness, direction and velocity of the wind, and the amount of rain. (8) Sometimes a soil covered with plants evaporates more than a free water surface. (9) The amount of water evaporated from a soil covered with plants and not irrigated can not be greater than the quantity received by the soil before or during the period of growth. But swamp lands, lands well irrigated, and free water surfaces evaporate, under favorable conditions, a greater quantity of water than corresponds to the precipitation during the same time. (10) the evaporating power of a soil depends on its physical properties. With less permeability, larger capacity for water and greater capillary power, evaporation is more active. (11) Soil with plants evaporates more as the plants are better developed, stand closer together, or have longer period of growth and vice versa.

1896.

Boggs, Edward M.
Arizona weather. Arizona exp. sta. bul., 1896, No. 20.

Evaporation at Tucson, Ariz., was observed by means of a galvanized-iron tank, 6 by 4 by 4 feet, sunk in the ground. The water always stood within *a few inches* of the top, and its level was read by means of a Boyden hook gage reading directly to 0.001 foot, placed in a still well about 10 inches from the tank and connected therewith by a pipe of small diameter. The tank was in a fenced inclosure, fully exposed to the wind. The observations from December, 1891, to June, 1895, showed an annual evaporation of 77.7 inches, somewhat less than is commonly attributed to this region. The evaporation from a second tank containing growing waterlillies was only 1 per cent less than from the first.

Bühler, A.
Untersuchungen über die Verdunstung des Wassers aus dem Boden. Mitt. Schweiz. Centralanst. forstl. Versuchsw., 1895(?), **4**:315. Reviewed in Met. Zeits., 1896, **13**:(22); Mo. weather rev., 1896, **24**:374; Ciel et terre, 1896, **17**:21–2.

Experiments were made at Adlisburg from June 27 to September 1, 1894, with evaporation from loamy clay in five metal boxes, 20 centimeters square and 10 centimeters high, one placed level and four on an incline of 30° and facing the four cardinal points of the compass. The following rates were obtained: Horizontal, 100; north exposure, 91; east exposure 87.5; south exposure, 100.5; west exposure, 100.5. The ratios for differently shaded plots were: for unprotected soil, 100; one-fourth covered, 88; one-half covered, 71; three-fourths covered, 62. Evaporation was found to be the most rapid from noon to 3 p. m.

Crosby, D. J.
Temperatures and evaporation in different soils. Michigan exp. sta. bul., No. 125, p. 30–2. Quoted in Exp. sta. rec., 1896, **7**:373–5.

In experiments on evaporation from sand, clay, loam, and muck, it was found that the sand lost water most rapidly; loam, clay, and muck following in the order named. The surface temperature, however, was highest in muck and lowest in sand, but at depths of 3 and 6 inches the sand was the warmer. When the light-colored sand was covered with lamp black and the dark-colored muck with white lime, this order of temperatures was reversed, showing that the color of the surface largely controlled the temperatures below.

Milne, John.
Movements of the earth's crust. Geog. jour., 1896, **7**:229–55.

On p. 242–3 the author discusses the influence of evaporation on the movements of the earth's crust. Applying the figures obtained by Miller, 1878, he shows that "the greatest displacement of a horizontal pendulum ought to be expected when such an instrument was placed on the boundaries of two areas respectively covered with soil and grass. On a fine day the differential evaporation effect on the two sides of the instrument would be equivalent to moving a load of about 2.5 tons per 29 yards square from the ground covered with grass, which is quite sufficient to produce many of the observed effects."

Müller, P. A.
Ueber die Temperatur und Verdunstung der Schneeoberfläche und der Feuchtigkeit in ihre Nähe. Mem. acad. imp. sci., St. Pétersbourg, Phys. Math. Cl., 1896, **5** (8), No. 1. Also St. Petersburg. 1896. 38 p. 4to. Review in Met. Zeits., 1897, **14**: (12).

Discusses observations on the surface temperature of snow, the temperature and relative humidity of the air in its neighborhood, and its evaporation. The author emphasizes the point that condensation occurs when the difference between the dew-point of the air and the temperature of the surface of the snow is positive, evaporation occuring when this difference is negative.

Penck, A[lbrecht].
Untersuchungen über Verdunstung und Abfluss von grösseren Landflächen. Geog. Abh., 1896, **5**:461–508. Review in Met. Zeits., 1897, **14**: (55). Abstract in Geog. jour., 1897, **9**:563–4.

Studies of the monthly variations in the relation between the rainfall, drainage, and evaporation of the river Elbe in Bohemia. The average rainfall for 1888–1890 was 696 millimeters, runoff, 214 millimeters, and evaporation, 482 millimeters, the evaporation factor being 69.2 per cent of the total loss. The average evaporation factor for 1893–4 was 76 per cent. Richter's (1895) similar factor for the latter period is quoted. Evaporation is further arranged according to temperature, rainfall, seasons, etc., and formulas for determining the same are devised.

Phillips, W. F. R.
Sunstroke in California and Arizona. Mo. weather rev., 1896, **24**:454–6.

Quotes Fitzgerald's (1886) formula for calculating evaporation, in connection with an investigation of the evaporation from the human body to prove that, in accordance with statistics, sunstrokes occur as often in localities where the relative humidity is low as where it is high.

Schierbeck, N. P.
Oversigt over det Kongelige Danske Videnskabernes Selskabs Forhandlingar, 1896, No. 1. Copenhagen.

A mathematical treatment of the subject of evaporation. (See Schwalbe, 1902, for his formula.)

Symons, G. J., and H. Sowerby Wallis.
Evaporation. Brit. rainf., 1896, (—):27–31.

Tables give daily evaporation at Camden Square, Middlesex, Isfield Place, Sussex, Otterbourne, Hampshire, and Kennick Reservoir, Devon, from July, 1896, to June, 1897.

Trabert, Wilhelm.
Neue Beobachtungen über die Verdampfungsgeschwindigkeit. Met. Zeits., 1896, **13**:261–3.

The formulas of Dalton, Stefan, and Schierbeck are presented. The author's own formula, a modification Schierbeck's (1896), is $V=k(1+\alpha t)w^{\frac{1}{2}}(e_s-e)$. Where V=the rate of evaporation, k=a constant, α=1/273, w=the wind velocity, t=the air temperature, e_s=the maximum vapor pressure at the temperature of the water, and e that at the temperature of the air. But $(e_s-e)=(e_s-e_s')(e_s'-e)$, where e_s' is the maximum vapor pressure at the temperature of the wet-bulb. The readings of the wet- and dry-bulb thermometers are believed to offer a better and more practical method of determining evaporation than the direct observation of the loss in weight due to evaporation.

Twigg, R. H.
Evaporation at Kimberley, South Africa. Quart. jour. roy. met. soc., 1896, **22**:166. Review in Met. Zeits., 1896, **13**:279.

The evaporation gage of the Kimberley Waterworks Co. is a wrought-iron tank 4 by 4 by 4 feet, sunk in the ground to within an inch of the top and kept nearly full of water. Daily readings were made with a hook-gage designed by the author which allows readings to 1/1000 inch. A table shows the monthly evaporation from January, 1891, to January, 1895.

1897.

Abbe, Cleveland.
Evaporation at Fort Collins, Colo. Mo. weather rev., 1897, **25**:211.

Summarizes Carpenter's (1889) experiments with evaporation, and quotes his formula.

Alston, Garwood.
Comparison of evaporation results in New South Wales and South Africa. Trans. So. African phil. soc., 1897, **9**:8–19.

A comparison of the results obtained in New South Wales by Russell (1888–1904), and those obtained by the author from a reservoir at Van Wyks Vley shows 41 inches at Lake George, N. S. W., and 66 inches at Van Wyks Vley. At other Australian stations the evaporation varies from 28 to 60.5 inches.

Barnes, Nathan H.
Arizona weather climate. Arizona exp. sta. bul., 1897, No. 27.

This is, with a few changes and additions, the paper by Boggs, 1896.

Bruyn, H. E., de.
Mededeeling over de betrekking tusschen regenvall, verdamping en waterafooer. The Hague. 1897. 14 p. 4to. Review in Met. Zeits., 1897, **14**:(66).

Canestrini, Eugenio.
Sull' evaporazione del' acqua da superficie acquea, terrosa, ed erbosa. Atti soc. veneto-trentina sci. nat., 1897, **3**(2d. ser.):295–305.

In connection with experiments with evaporation from soils with and without vegetation, references are made to Schübler, 1831, Masure, 1880, Haberlandt, 1877, Risler, 1869–70–71, Hellriegel, 1883, and Woliny, 1895. From the author's own experiments he concludes in general that: (1) a soil constantly saturated evaporates more water in a year than a free water surface; (2) a soil with growing grain evaporates much more than a bare soil.

Davis, Arthur Powell.
Irrigation near Phoenix, Ariz. Water sup. and irr. papers, 1897, No. 2.

On p. 83–5 discusses methods for reducing evaporation from reservoirs in Arizona, and proposes to cover the surface of the water with a film of crude petroleum.

[*To be continued.*]

THE WEATHER OF THE MONTH.

By Mr. P. C. DAY, Acting Chief, Climatological Division.

PRESSURE AND WINDS.

The distribution of the mean atmospheric pressure for April, 1909, over the United States and Canada is graphically shown on Chart VI, and the average values and departures from the normal are shown for each station in Tables I and III.

The average atmospheric pressure during April, 1909, was decidedly high over the north Pacific coast and the adjacent portions of British Columbia, the excess above the normal pressure amounting to from .10 to .20 inch. Pressure was also comparatively high over the entire Atlantic coast districts, the maximum departures, about +.10 inch, occurring over the extreme eastern portion of the Canadian Maritime Provinces, and it was also above the normal by smaller amounts over all southern districts from the Atlantic to the Pacific.

The average pressure was below the normal from .05 to .10 inch over the upper Lake region, the upper Mississippi Valley, and the adjoining districts of Canada.

Marked increases in the mean pressure of the month over that for March, 1909, occurred over all eastern districts of the United States and Canada, the maximum excess ranging from .25 to .30 inch over the Canadian Maritime Provinces. From the Rocky Mountains westward to the Pacific, including the Northwest Provinces of Canada, there was also a marked increase in pressure over that for the preceding month.

Between the Rocky Mountains and the Mississippi Valley there was a general but comparatively small decrease in pressure from that of the preceding month.

With decreasing pressure from the Atlantic and Gulf coasts westward and northward to the Lake region the winds over all eastern and southern districts were largely from the south. High pressure over the north Pacific coast, diminishing eastward and southward, gave prevailing northerly and westerly winds from the Lake region and middle Missouri Valley to the Pacific. April was a comparatively windy month, the average hourly movement of the wind exceeding the normal over nearly all districts, the excess being especially marked in the Mississippi and Ohio valleys and Lake region, where it ranged from 10 to 40 per cent of the normal wind movement.

TEMPERATURE.

The month opened with cool weather prevailing over nearly all districts, the line of freezing temperature extending from northwestern Texas to the Lake region.

Cool, showery weather continued over most districts till the 5th, when decidedly warm weather dominated the more eastern districts, but over the mountain regions of the West cool weather still continued.

From the 5th to the 8th a storm of wide extent moved from the southern Rocky Mountain region to the Great Lakes and New England, accompanied by heavy rains in the central valleys during the 6th and 7th, and by light snows in portions of the Plains region and northern districts. Cool weather again dominated nearly all sections until the end of the first decade.

The mean temperature during this decade was generally below the normal in all districts between the Rocky and Appalachian mountains and over the Northwest. It was generally above normal over the Atlantic coast districts, the middle and southern Plateau regions, and over most of California.

The second decade of the month opened with a well-defined storm area over the central valleys, with warm weather over eastern districts and cool weather over the Great Plains and mountain regions. The storm area moved eastward during the 13th and 14th, with heavy rains in nearly all districts, followed by generally cold weather for the season, with frosts as far south as the central portions of Louisiana and Mississippi.

Warm weather prevailed during the latter part of the decade over most of the districts east of the Mississippi River, but over the Plains region and the Northwest the weather continued cold and unseasonable.

The mean temperature during the second decade continued below the normal over the districts between the Mississippi River and the Rocky Mountains and generally over the Northwest. It continued above the normal, as in the previous decade, over the Atlantic coast districts and from central Texas westward to the Pacific and over most of California and Nevada.

The last decade of the month was marked by unseasonably cold, cloudy weather, with frequent showers, followed during the last two or three days of the month by a storm of unusual severity that developed over the Great Plains on the 28th and moved eastward during the 29th and 30th.

The month closed with unseasonably cold weather, snow, and rain over the districts between the Rocky Mountains and the Mississippi River, and with warmer, but cloudy, rainy weather over the more eastern districts.

The mean temperatures during this decade continued below the normal, as in the previous decades, over the central valleys and the Northwest, and it was also below normal over all the remaining portions of the United States, except the south Atlantic and east Gulf States, portions of the west Gulf States, and the south Pacific coast.

PRECIPITATION.

The precipitation was generally abundant and well distributed during the month over all districts east of the Mississippi River, except over the eastern slope of the Appalachian Mountains from Maryland to central South Carolina and in portions of Florida.

Over much of the Lake region, the eastern portion of the Mississippi Valley, and in portions of the Ohio Valley, the interior of the east Gulf States, and the northern portion of the Appalachian Mountain district the rainfall was heavy, ranging generally from 2 to 4 inches above the normal, and at points in central Alabama the excess amounted to from 6 to 8 inches.

Precipitation was generally deficient in the districts west of the Mississippi River, except locally at points in the mountain regions of Montana and Colorado. There was a general deficiency of about 2 inches over most of Texas, and over large portions of the Great Plains the deficiency ranged from 1 to 2 inches. Over the Pacific slope rainfall was everywhere deficient, being especially pronounced in northern California and over northwestern Oregon and western Washington, where the fall was generally less than 50 per cent of the normal. In California the month as a whole was one of the driest on record. At the end of the month rain was badly needed in Arizona and New Mexico, and over most of Texas drought conditions existed. East of the Mississippi rainfall was needed in portions of North Carolina and South Carolina, and central Florida. Heavy rains during the night of April 30 and May 1 relieved the dry conditions in the last-named districts, however, except in portions of Florida.

Storms during the last few days of the month over the central valleys were severe and widespread, bringing heavy rains, severe thunderstorms, high winds, and tornadoes to many portions of the Mississippi and Ohio valleys, Gulf States, and Great Lakes. More than one hundred persons were killed, many more injured, and much damage was done to property, full accounts of which appear in other portions of the REVIEW.

SNOWFALL.

Snow in measurable quantities occurred over the entire northern half of the country, and traces of snow occurred as

far south as the northern portions of the cotton belt. Snow was unusually heavy in the upper Lake region and upper Mississippi Valley, and there were some heavy falls in the central Rocky Mountain districts, especially in Colorado, where the snowfall for the month exceeded the amount melted, the amount of snow on the ground at the end of the month being greater than at the beginning. At the end of the month the ground was free of snow in all districts, except along the northern border from New England to North Dakota, and over the mountain districts of the West. A heavy covering, ranging from 5 to 15 and 20 inches, remained on the ground in the northern portions of Michigan, Wisconsin, and Minnesota, and there was a heavy accumulation of snow in nearly all the mountain districts of the West. Melting had proceeded but slowly on account of the prevailing cool weather, and the snow was reported to be in condition to furnish a good supply of water until late in the coming summer.

HUMIDITY AND SUNSHINE.

The relative humidity was below the normal on the Pacific coast and the middle and southern portions of the districts between the Mississippi River and the Rocky Mountains, and at a few points on the middle Atlantic coast. From New England westward to the Great Lakes the humidity was generally above the normal, and there was a general and well-marked excess of humidity in most of the mountain and Plateau regions.

Cloudy weather was general over the northern tier of States from New England westward to the Pacific. Over all southern districts, however, much less cloudiness prevailed, the percentage of sunshine ranging between 50 and 60 per cent of the possible amount over the South Atlantic and Gulf States, and from 70 to 90 per cent over the Southwest.

Average temperatures and departures from the normal.

Districts.	Number of stations.	Average temperatures for the current month.	Departures for the current month.	Accumulated departures since January 1.	Average departures since January 1.
		°	°	°	°
New England	12	43.4	− 0.3	+ 5.0	+ 1.2
Middle Atlantic	16	51.8	+ 1.0	+11.0	+ 2.8
South Atlantic	10	63.4	+ 2.2	+11.7	+ 2.9
Florida Peninsula*	8	72.4	+ 2.2	+14.0	+ 3.5
East Gulf	11	64.7	+ 0.1	+ 8.7	+ 2.2
West Gulf	10	64.5	− 1.0	+ 9.4	+ 2.4
Ohio Valley and Tennessee	13	54.8	− 0.2	+ 9.4	+ 2.4
Lower Lake	10	43.6	− 1.1	+ 7.1	+ 1.8
Upper Lake	12	37.5	− 2.9	+ 5.4	+ 1.4
North Dakota*	9	34.2	− 6.5	− 2.0	− 0.5
Upper Mississippi Valley	15	46.9	− 3.6	+ 5.3	+ 1.3
Missouri Valley	12	46.9	− 3.6	+ 5.4	+ 1.4
Northern Slope	9	37.4	− 5.4	− 1.7	− 0.4
Middle Slope	6	50.6	− 3.1	+ 3.7	+ 0.9
Southern Slope*	7	60.7	− 0.7	+ 8.1	+ 2.0
Southern Plateau*	12	54.9	− 1.6	− 2.4	− 0.6
Middle Plateau*	10	44.6	− 2.3	+ 3.1	+ 0.8
Northern Plateau*	12	43.7	− 3.2	+ 1.6	+ 0.4
North Pacific	7	47.4	− 1.0	− 4.0	− 1.0
Middle Pacific	8	57.1	+ 1.7	+ 2.8	+ 0.7
South Pacific	4	59.6	+ 1.6	+ 1.8	+ 0.4

* Regular Weather Bureau and selected cooperative stations.

In Canada.—Director R. F. Stupart says:

The temperature over the Dominion was below the average, except in portions of Prince Edward Island and Cape Breton, where the average was somewhat exceeded. The negative departures were marked, especially so in the Western Provinces, where they ranged from 9° to 12°. The northern portions of British Columbia, Ontario, and Quebec also recorded as much as 7° and 8° below the normal.

In British Columbia the precipitation was much below the average amount, except in Cariboo, where there was more than usual. In Alberta and Saskatchewan there was a positive amount in some districts and a negative in others. Calgary recorded 100 per cent above the average, while Battleford experienced nearly 100 per cent below the average quantity. In Manitoba the excess throughout the Province ranged from 31 to about 50 per cent; elsewhere in the Dominion the precipitation was largely above the average, except in the eastern portion of Quebec and in parts of Prince Edward Island and Cape Breton, where the deficiency was rather marked. In the Province of Ontario the positive departure was very generally from 2 to 4 inches. Snow fell at intervals, the usual April snowfall record in the several provinces being as a rule much exceeded.

Average precipitation and departures from the normal.

Districts.	Number of stations.	Average.		Departure.	
		Current month.	Percentage of normal.	Current month.	Accumulated since Jan. 1.
		Inches.		*Inches.*	*Inches.*
New England	12	4.58	149	+ 1.5	+ 3.0
Middle Atlantic	16	3.65	129	+ 0.6	− 0.6
South Atlantic	10	3.73	109	+ 0.3	− 3.5
Florida Peninsula*	8	2.70	129	+ 0.6	− 2.6
East Gulf	11	7.37	181	+ 3.3	+ 2.7
West Gulf	10	2.50	71	− 1.0	− 5.4
Ohio Valley and Tennessee	13	5.09	138	+ 1.4	+ 2.4
Lower Lake	10	3.64	156	+ 1.3	+ 3.3
Upper Lake	12	4.77	230	+ 2.7	+ 2.3
North Dakota*	9	0.85	52	− 0.8	− 1.9
Upper Mississippi Valley	15	5.40	180	+ 2.4	+ 3.1
Missouri Valley	12	2.19	147	+ 0.7	+ 0.5
Northern Slope	9	1.02	63	− 0.6	− 0.7
Middle Slope	6	1.62	73	− 0.6	− 0.9
Southern Slope*	7	0.80	33	− 1.6	− 2.9
Southern Plateau*	12	0.16	24	− 0.5	− 0.7
Middle Plateau*	10	0.94	76	− 0.3	+ 0.4
Northern Plateau*	12	0.63	36	− 1.1	− 0.4
North Pacific	7	0.92	28	− 2.4	− 0.8
Middle Pacific	8	0.04	2	− 1.9	+ 7.9
South Pacific	4	0.01	1	− 1.0	+ 5.8

* Regular Weather Bureau and selected cooperative stations.

Maximum wind velocities.

Stations.	Date.	Velocity.	Direction.	Stations.	Date.	Velocity.	Direction.
Alpena, Mich	7	52	w.	Mount Tamalpais, Cal	4	56	nw.
Bismarck, N. Dak	2	52	nw.	Do	18	61	nw.
Block Island, R. I	8	60	w.	Do	19	71	nw.
Buffalo, N. Y	7	75	sw.	Do	20	72	nw.
Do	8	64	w.	Do	26	53	nw.
Do	13	54	s.	Do	27	84	nw.
Do	21	54	sw.	Do	28	74	nw.
Do	25	50	sw.	Mount Weather, Va	7	57	nw.
Burlington, Vt	12	55	s.	Nashville, Tenn	3	52	w.
Do	13	50	s.	Do	12	54	se.
Canton, N. Y	7	64	sw.	Do	19	54	s.
Do	8	65	w.	New York, N. Y	7	83	w.
Do	21	61	se.	Do	8	54	w.
Chicago, Ill	7	60	w.	North Head, Wash	9	52	nw.
Do	29	50	e.	Oklahoma, Okla	11	54	s.
Cleveland, Ohio	7	50	sw.	Do	25	70	n.
Do	13	58	se.	Oswego, N. Y	13	50	s.
Do	21	66	w.	Pittsburg, Pa	7	68	w.
Columbia, Mo	6	52	sw.	Do	13	52	se.
Columbus, Ohio	3	50	nw.	Do	29	62	n.
Do	7	60	nw.	Point Reyes Light, Cal	3	93	nw.
Do	21	54	w.	Do	4	76	nw.
Corpus Christi, Tex	5	54	se.	Do	10	74	nw.
Do	7	55	ne.	Do	18	78	nw.
Des Moines, Iowa	11	53	sw.	Do	19	79	nw.
Detroit, Mich	7	70	sw.	Do	20	77	nw.
Do	12	50	s.	Do	21	73	nw.
Do	21	58	w.	Do	27	73	nw.
Do	29	54	nw.	Do	28	70	nw.
Duluth, Minn	26	50	w.	Port Huron, Mich	7	54	w.
Do	29	60	ne.	Providence, R. I	8	50	nw.
Do	30	50	ne.	Richmond, Va	3	52	nw.
El Paso, Tex	5	60	w.	Rochester, N. Y	7	58	w.
Do	11	52	w.	St. Paul, Minn	7	50	nw.
Do	20	58	w.	Santa Fe, N. Mex	11	51	sw.
Evansville, Ind	29	50	s.	Sioux City, Iowa	2	54	nw.
Grand Rapids, Mich	7	52	sw.	Do	28	56	nw.
Green Bay, Wis	7	58	nw.	Southeast Farallon, Cal	3	58	nw.
Indianapolis, Ind	12	56	s.	Do	4	60	n.
Do	29	50	s.	Do	19	55	nw.
Kansas City, Mo	4	50	s.	Syracuse, N. Y	7	58	sw.
Do	29	50	s.	Do	8	58	sw.
La Salle, Ill	6	60	sw.	Do	13	58	s.
Lexington, Ky	29	64	sw.	Do	21	54	s.
Lincoln, Nebr	28	60	nw.	Toledo, Ohio	6	50	sw.
Little Rock, Ark	29	50	nw.	Do	7	70	sw.
Madison, Wis	11	51	s.	Do	12	57	s.
Marquette, Mich	11	54	s.	Do	13	61	s.
Milwaukee, Wis	28	52	e.	Do	21	60	sw.
Do	29	54	ne.	Tonopah, Nev	29	54	nw.
Minneapolis, Minn	7	52	w.	Topeka, Kans	11	54	s.
Mount Tamalpais, Cal	3	62	nw.				

Average relative humidity and departures from the normal.

Districts.	Average.	Departure from the normal.	Districts.	Average.	Departure from the normal.
New England	75	+ 2	Missouri Valley	61	— 4
Middle Atlantic	69	+ 2	Northern Slope	66	+ 8
South Atlantic	73	+ 1	Middle Slope	58	+ 1
Florida Peninsula	79	+ 5	Southern Slope	47	— 8
East Gulf	72	+ 2	Southern Plateau	35	+ 2
West Gulf	71	— 1	Middle Plateau	47	+ 3
Ohio Valley and Tennessee	65	0	Northern Plateau	52	— 6
Lower Lake	72	+ 2	North Pacific	74	— 3
Upper Lake	77	+ 4	Middle Pacific	63	— 9
North Dakota	74	+ 6	South Pacific	67	— 1
Upper Mississippi Valley	68	0			

Average cloudiness and departures from the normal.

Districts.	Average.	Departure from the normal.	Districts.	Average.	Departure from the normal.
New England	6.0	+ 0.7	Missouri Valley	5.6	+ 0.2
Middle Atlantic	5.5	+ 0.3	Northern Slope	5.9	+ 0.5
South Atlantic	5.0	+ 0.6	Middle Slope	4.7	+ 0.3
Florida Peninsula	4.3	+ 0.4	Southern Slope	3.5	— 0.7
East Gulf	5.0	+ 0.5	Southern Plateau	1.6	— 0.7
West Gulf	4.6	— 0.6	Middle Plateau	3.8	— 0.7
Ohio Valley and Tennessee	5.6	+ 0.3	Northern Plateau	5.6	— 0.7
Lower Lake	6.6	+ 1.1	North Pacific	5.4	— 1.1
Upper Lake	6.8	— 1.1	Middle Pacific	2.4	— 2.2
North Dakota	5.7	+ 0.2	South Pacific	3.2	— 0.7
Upper Mississippi Valley	6.1	+ 0.6			

CLIMATOLOGICAL SUMMARY.

By Mr. P. C. DAY, Acting Chief, Climatological Division.

TEMPERATURE AND PRECIPITATION BY SECTIONS, APRIL, 1909.

In the following table are given, for the various sections of the Climatological Service of the Weather Bureau, the average temperature and rainfall, the stations reporting the highest and lowest temperatures with dates of occurrence, the stations reporting greatest and least monthly precipitation, and other data, as indicated by the several headings.

The mean temperatures for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperature and precipitation are based only on records from stations that have ten or more years of observation. Of course the number of such records is smaller than the total number of stations.

Section.	Temperature—in degrees Fahrenheit.							Precipitation—in inches and hundredths.					
	Section average.	Departure from the normal.	Monthly extremes.					Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest. Date.			Station.	Amount.	Station.	Amount.
Alabama	63.3	+ 0.6	Thomasville	94	18	Riverton	29 13	6.96	+ 3.25	Anniston	12.15	Lucy	3.21
Arizona	60.0	— 1.2	Quartzsite	104	28	Keams Canyon	11 8	0.12	— 0.39	Greer	0.72	32 stations	0.00
Arkansas	60.9	— 0.4	Arkadelphia (near)	88	28	Pond	24 9	4.52	+ 0.27	Huttig	8.79	Centerpoint	1.66
			Dodd City	88	18								
California	57.6	+ 1.7	Heber	102	7	Tamarack	9 11, 22	0.12	— 1.80	Towle	1.75	100 stations	0.00
Colorado	40.3	— 3.9	Las Animas	91	17	Wagon Wheel Gap	—17 6	1.86	— 0.15	Corona	9.67	Sheridan Lake	0.29
Florida	71.2	+ 2.1	Brooksville, Plant City.	97	30	Marianna	25 10	2.75	+ 0.39	Molino	11.72	Live Oak	0.08
Georgia	63.8	+ 1.1	Blakeley	94	5, 22	Clayton	27 10	3.70	+ 0.18	Clayton	8.82	Camak	1.34
Hawaii (March)	66.9		Kealia, Kauai	87	29	Humuula, Hawaii	32 1, 25	15.94		Honomanu Valley, Maui.	63.63	Makapuu Point, Oaku.	0.43
Idaho	41.7	— 3.6	Hotspring	80	19	Paris	— 9 5	0.53	— 0.64	Dent	2.40	3 stations	0.00
Illinois	50.2	— 1.5	5 stations	88	3 d't's	Antioch	11 5	6.23	+ 2.94	Sullivan	10.74	Olney	3.44
Indiana	50.8	— 1.4	Rome	86	17, 18	Knox	12 10	5.16	+ 2.05	Rome	7.98	Elkhart	3.20
			Madison	86	18								
Iowa	43.8	— 4.7	Burlington	86	29	Elma, Fayette	14 10	4.58	+ 1.75	New Hampton	9.43	Hancock	0.83
Kansas	53.0	— 1.8	Ulysses	98	17	Jewell	17 8	1.43	— 1.25	Kansas City	4.20	3 stations	T.
Kentucky	56.1	+ 0.1	Catlettsburg	96	18	Beattyville	21 11	5.98	+ 2.33	Taylorsville	11.02	Pikeville	3.32
						Williamsburg	21 10						
Louisiana	66.6	— 0.3	6 stations	90	3 d't's	Minden	30 9	5.18	+ 0.75	Amite	10.99	Sugartown	1.92
Maryland and Delaware	52.7	+ 0.9	4 stations	89	19	Deer Park, Md	50 11	3.59	+ 0.32	Deer Park, Md., Oakland, Md.	6.16	Coleman, Md	1.94
Michigan	39.2	— 3.1	Arbela	82	5	Watersweet	—16 10	4.95	+ 2.02	Croton	11.04	Gaylord	1.19
Minnesota	35.8	— 7.3	Lynd	76	26	Stephens Mine	— 5 10	1.89	— 0.20	Caledonia	5.77	Beaulieu, Rosenu	0.34
Mississippi	64.2	+ 0.1	Hattiesburg	90	30	Ripley	29 9	6.85	+ 2.44	Macon	12.58	Hazlehurst	3.76
Missouri	54.8	— 0.9	Gano	93	29	Mexico	19 10	4.35	+ 0.67	Ironton	8.49	Arthur	1.31
						Lamar	19 13						
Montana	36.0	— 6.4	Poplar	78	14	Bowen	—12 6	1.24	— 0.02	Evans	5.89	Culbertson	0.02
Nebraska	44.8	— 4.2	Beaver City	94	26	Valentine	13 8	1.06	— 1.49	Auburn	2.41	Wisner	0.19
Nevada	47.8	+ 0.7	Logan	98	27	3 stations	10 3 d't's	0.18	— 0.56	McAfees Ranch	0.89	7 stations	0.00
New England*	43.0	— 0.5	Nashua, N. H	86	19	Van Buren, Me	2 2	4.59	+ 1.46	Canton, Conn	8.25	Cornwall, Vt	1.93
			Westboro, Mass	86	19								
New Jersey	50.2	+ 0.8	Indian Mills, Lakewood.	88	19	Newton	17 11	5.97	+ 2.51	Charlotteburg	8.90	Bridgeton	3.99
New Mexico	51.4	— 1.6	Carlsbad	100	18	Vermejo Park	— 1 8	0.29	— 0.40	Chama	1.66	33 stations	0.00
New York	42.9	— 0.7	West Point	88	20	Franklinville	— 1 11	3.67	+ 0.99	Scarsdale	7.96	Lyndonville	1.33
North Carolina	60.1	+ 2.6	Clinton	93	6	Banners Elk	18 11	4.16	+ 0.32	Selma	9.90	Troy	1.30
						Mount Airy	18 11						
North Dakota	34.2	— 6.9	Aplin	80	19	Crosby	3 13	0.81	— 0.68	Wahpeton	2.27	Portal	0.00
Ohio	49.1	— 0.4	Ironton	90	18	Hudson	13 11	4.13	+ 1.32	New Alexandria	6.28	Bowling Green	2.43
						Wooster	13 10						
Oklahoma	59.4	— 0.7	Cloudchief	99	18	Hurley	16 7	1.47	— 1.49	Webbers Falls	4.33	3 stations	T.
Oregon	47.0	— 1.5	Glendale	88	29	Granite	8 7	0.84	— 2.11	Pompeii	6.19	Warmspring, Prineville.	0.00
Pennsylvania	48.5	+ 0.3	3 stations	87	18, 19	Somerset	8 11	5.39	+ 2.29	Drifton	8.42	Kennett Square, Harrisburg.	2.67
Porto Rico	75.2	— 0.5	Manati	99	29	Cayey	50 3 d't's	5.17	+ 0.08	Maricao	10.73	Santa Isabel	1.04
South Carolina	63.9	+ 2.6	Florence	86	18	Dillon	30 10	2.95	— 0.19	Effingham	6.20	Blairs	0.68
South Dakota	39.7	— 6.0	Fairfax, Greenwood	83	17	4 stations	8 4 d't's	1.06	— 1.28	Deadwood	4.40	Farmingdale	0.02
Tennessee	58.9	+ 0.9	Carthage	90	18	Mountain City	18 10	5.41	+ 1.35	Milan	8.40	Bristol	2.35
Texas	66.1	— 0.7	Zapata	111	29	Tulia	16 1	1.55	— 1.39	Henderson	4.93	4 stations	0.00
Utah	44.7	— 3.5	St. George	87	15, 16	Strawberry Valley	— 4 4	1.13	— 0.22	Schofield	7.49	Kelton, Lon	0.00
Virginia	55.3	+ 1.5	Doswell	91	18	Burkes Garden	12 11	3.38	+ 0.10	Elk Knob	5.16	Charlottesville	1.75
Washington	46.8	— 2.1	Centralia	81	8	Trinidad	14 3	1.01	— 1.43	Clearwater	4.66	3 stations	0.00
West Virginia	53.0	+ 1.9	Williamson	93	18	Bayard	10 11	5.04	+ 1.54	Pickens	8.57	Elkhorn	1.70
Wisconsin	37.5	— 6.9	Port Washington	75	5	Vudesare	—16 10	4.79	+ 2.35	Lake Mills	8.58	Spooner	1.44
Wyoming	34.8	— 5.4	3 stations	78	17	Tower Falls, Y. N. P.	—14 6	1.15	— 0.44	Eatons Ranch	4.80	Worland	0.09

*Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, and Connecticut.

DESCRIPTION OF TABLES AND CHARTS.

By Mr. P. C. DAY, Acting Chief, Climatological Division.

For description of tables and charts see page 34 of REVIEW for January, 1909.

TABLE I.—*Climatological data for U. S. Weather Bureau stations, April, 1909.*

Stations.	Elevation of instruments.			Pressure, in inches.			Temperature of the air, in degrees Fahrenheit.										Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity, per cent.	Precipitation, in inches.			Wind.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness during daylight, tenths.	Total snowfall.
	Barometer above sea level, feet.	Thermometers above ground.	Anemometer above ground.	Actual, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hrs.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with .01, or more.	Total movement, miles.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.				
New England.							43.4	— 0.3											75	4.58	+ 1.5								6.0	
Eastport	76	67	85	29.93	30.02	+ .09	37.8	— 0.5	56	13	44	18	1	32	20	34	31	79	3.86	+ 0.9	17	9,292	s.	42	e.	26	7	8	15	6.7	11.7
Greenville	1,070	6	....	28.84	30.03	.....	33.8	.....	58	5	43	4	12	24	42	.....	.....	.....	.....	4.22	.....	16	.....	se.	.....	.....	.....	.....	.....	.....	.....	.....
Portland, Me.	103	81	117	29.92	30.05	+ .09	40.8	— 2.2	63	22	47	22	11	34	24	37	32	73	3.13	0.0	12	7,901	s.	42	nw.	4	9	9	12	5.8	T.
Concord	288	70	79	29.73	30.05	+ .06	43.8	0.0	83	19	54	21	12	33	45	.....	.....	.....	.....	3.04	+ 0.2	14	5,104	se.	31	w.	8	7	14	9	6.1	1.7
Burlington	404	11	43	29.59	30.04	+ .05	39.6	— 1.1	70	7	48	21	2	32	27	.....	.....	.....	.....	2.67	+ 0.8	16	10,357	s.	55	s.	12	3	14	13	7.2	2.7
Northfield	876	16	70	29.08	30.05	+ .06	38.5	— 1.7	77	19	48	13	2	29	41	34	29	71	2.43	+ 0.3	16	7,644	n.	42	se.	27	4	13	13	7.0	4.5
Boston	125	115	188	29.92	30.06	+ .09	47.8	+ 2.5	83	19	56	25	11	39	33	42	38	73	3.92	+ 0.4	12	8,730	sw.	43	nw.	8	8	10	12	6.4	
Nantucket	12	14	90	30.04	30.05	+ .08	44.2	0.0	59	5	50	27	11	39	21	41	38	84	4.40	+ 1.8	10	13,406	s.	46	sw.	19	9	12	9	5.7	T.
Block Island	26	11	46	30.02	30.06	+ .08	44.0	+ 0.2	56	19	49	26	11	39	16	41	38	81	7.97	+ 4.4	13	13,663	sw.	60	w.	8	11	8	11	4.9	0.8
Narragansett	....	9	....	....	....	....	43.8	— 0.8	60	7	52	21	11	36	25	.....	.....	.....	.....	6.35	.....	14	.....	sw.	.....	.....	.....	19	1	10	.....	0.5
Providence	160	141	165	29.89	30.07	+ .09	46.1	— 0.5	78	19	55	22	11	37	32	41	35	70	5.07	+ 1.5	15	8,907	nw.	50	nw.	8	8	13	9	5.3	1.0
Hartford	159	122	140	29.89	30.07	+ .08	46.8	+ 0.1	77	19	56	23	11	38	30	42	37	75	7.21	+ 3.6	14	7,012	s.	40	s.	13	6	13	11	6.9	0.7
New Haven	106	116	155	29.94	30.06	+ .07	47.2	+ 0.8	74	7	55	23	11	39	26	41	35	67	6.66	+ 3.1	14	8,023	s.	48	w.	7	9	11	10	5.4	2.0
Mid. Atlantic States.							51.8	+ 1.0											69	3.65	+ 0.6								5.5	
Albany	97	102	115	29.95	30.06	+ .06	45.4	— 0.8	86	19	55	24	11	36	43	39	33	68	2.12	— 0.3	13	7,521	nw.	42	sw.	13	8	16	6	5.3	T.
Binghamton	871	78	90	29.11	30.05	+ .03	43.6	— 0.8	80	19	53	16	11	34	64	.....	.....	.....	.....	3.51	+ 1.3	17	6,024	w.	46	w.	8	3	5	22	7.5	2.6
New York	314	108	350	29.72	30.06	+ .06	49.5	+ 1.4	80	19	57	24	11	42	31	44	39	72	5.93	+ 2.6	15	10,429	nw.	83	w.	7	8	8	14	5.9	T.
Harrisburg	374	94	104	29.66	30.07	+ .05	50.0	— 0.7	84	19	60	26	11	40	32	43	36	66	2.67	+ 0.2	13	6,807	e.	42	w.	8	7	10	13	5.9	T.
Philadelphia	117	116	184	29.95	30.08	+ .07	53.2	+ 2.4	84	19	62	29	11	44	30	46	39	65	4.49	+ 1.6	12	8,557	nw.	38	nw.	7	11	6	13	5.6	
Scranton	805	111	119	29.18	30.06	+ .05	46.3	— 0.8	83	19	56	20	11	37	38	40	34	69	5.20	+ 2.6	15	5,708	sw.	40	w.	7	8	10	12	6.3	6.8
Atlantic City	52	37	48	30.01	30.07	+ .07	49.1	+ 1.5	71	7	55	26	11	43	24	45	41	76	4.54	+ 1.6	13	7,060	s.	32	s.	13	8	9	13	6.1	
Cape May	17	48	52	30.07	30.09	+ .10	50.5	+ 2.1	71	7	56	30	11	45	23	46	.....	.....	4.76	+ 1.8	12	7,710	s.	28	se.	13	12	6	12	5.2	T.
Baltimore	123	100	113	29.94	30.07	+ .06	53.9	+ 0.9	89	19	63	28	11	45	30	47	42	67	2.18	— 1.1	7	6,437	sw.	33	se.	13	10	6	14	6.0	T.
Washington	112	62	76	29.94	30.07	+ .05	54.2	+ 1.1	88	19	65	26	11	44	37	46	38	61	2.69	— 0.6	8	6,326	nw.	33	nw.	7	8	13	9	5.5	
Cape Henry	18	9	58	30.06	30.08	+ .08	57.6	+ 3.0	86	18	66	36	11	50	33	.....	.....	.....	.....	3.11	— 0.8	12	10,391	sw.	37	nw.	10	15	7	8	4.2	
Lynchburg	681	83	88	29.83	30.08	+ .06	57.2	+ 1.6	89	18	69	26	11	46	47	50	45	69	2.38	— 0.8	10	3,788	nw.	31	nw.	20	12	7	11	5.4	
Mount Weather	1,725	10	54	28.21	30.05	+ .03	48.7	+ 0.3	82	19	58	20	11	39	32	43	38	72	4.74	+ 1.7	11	12,284	nw.	57	nw.	7	7	11	12	5.7	0.2
Norfolk	91	102	111	30.00	30.09	+ .08	59.0	+ 3.0	86	6	68	36	11	50	36	52	48	72	3.11	— 0.7	12	8,009	s.	36	se.	13	15	3	12	4.7	
Richmond	144	145	153	29.94	30.10	+ .08	57.6	+ 0.4	89	18	69	30	11	47	41	.....	.....	.....	.....	3.21	— 0.2	10	7,185	se.	52	nw.	3	14	7	9	4.7	
Wytheville	2,293	40	47	27.67	30.05	+ .02	52.9	+ 0.9	82	6	64	29	11	42	39	46	42	71	3.73	+ 0.1	16	4,679	w.	30	w.	7	17	7	6	3.5	0.1
S. Atlantic States.							63.4	+ 2.2											73	3.73	+ 0.3								5.0	
Asheville	2,285	53	75	27.71	30.06	+ .03	56.2	+ 2.3	86	5	67	30	9	46	39	50	46	73	3.75	— 0.3	10	6,789	se.	35	se.	13	12	8	10	5.2	T.
Charlotte	773	68	76	29.25	30.09	+ .06	61.6	+ 2.4	83	5	71	33	11	52	29	53	46	62	3.99	+ 0.6	8	6,050	s.	33	w.	3	10	8	12	5.5	
Hatteras	11	12	47	30.09	30.10	+ .09	61.8	+ 3.8	77	19	68	43	11	56	21	58	55	83	7.95	+ 3.6	14	12,159	sw.	45	n.	23	19	6	5	3.8	
Manteo	....	....	....	....	....	....	60.2	.....	86	6	69	34	10	51	.....	.....	.....	.....	.....	7.08	+ 2.5	11	.....	sw.	.....	.....	.....	16	6	8	.....	.....
Raleigh	376	103	109	29.68	30.08	+ .05	61.2	+ 2.2	87	6	72	32	11	50	36	53	46	65	4.08	+ 0.6	10	7,065	sw.	36	s.	13	13	6	11	4.9	
Wilmington	78	81	91	30.02	30.11	+ .08	63.2	+ 2.8	85	6	72	38	1	54	28	57	52	76	3.76	+ 0.9	9	7,420	sw.	33	sw.	30	9	17	4	4.4	
Charleston	48	14	92	30.04	30.09	+ .06	65.4	+ 1.6	84	7	72	43	10	59	23	59	56	77	3.58	+ 0.6	8	8,662	sw.	38	e.	11	9	12	9	5.1	
Columbia, S. C.	351	41	57	29.70	30.08	+ .05	64.2	+ 1.4	87	6	75	37	10	54	35	55	48	63	1.72	— 1.1	11	5,978	sw.	32	sw.	23	10	10	10	5.4	
Augusta	180	89	97	29.89	30.08	+ .05	64.6	+ 1.4	86	5	75	36	10	54	34	56	50	66	1.40	— 2.1	8	4,910	se.	34	nw.	22	12	5	13	5.0	
Savannah	65	81	89	30.03	30.10	+ .07	66.2	+ 1.5	84	20	74	43	10	58	26	59	56	78	1.90	— 1.1	12	5,858	sw.	26	w.	3	10	9	11	5.4	
Jacksonville	43	96	129	30.04	30.09	+ .05	69.8	+ 2.2	87	23	78	46	10	62	25	64	62	84	1.80	— 0.9	9	7,042	s.	29	sw.	23	10	14	6	4.9	
Florida Peninsula.							74.4	+ 1.6											79	2.63	+ 0.8								4.3	
Jupiter	28	10	46	30.03	30.06	+ .02	73.7	+ 1.5	88	26	80	53	3	68	25	68	66	78	4.97	+ 2.3	9	10,162	s.	36	e.	11	7	16	7	5.3	
Key West	22	10	53	30.02	30.04	+ .02	76.6	+ 1.1	86	27	82	68	4	71	17	71	69	80	3.01	+ 1.7	7	6,755	se.	43	nw.	2	19	6	5	3.5	
Sand Key	25	41	71	30.00	30.03	+ .01	78.8	.....	87	28	78	67	2	73	12	.....	.....	.....	1.29	0.0	7	10,378	se.	48	nw.	2	22	5	3	3.5	
Tampa	35	79	96	30.04	30.08	+ .02	72.9	+ 2.3	90	29	82	53	10	64	30	66	63	80	1.25	— 0.6	6	5,967	ne.	31	nw.	13	7	19	4	4.9	
East Gulf States.							64.7	+ 0.1											72	7.37	+ 3.3								5.0	
Atlanta	1,174	190	216	28.84	30.08	+ .05	61.2	+ 0.1	82	18	71	38	9	52	35	53	47	64	5.77	+ 2.1	10	7,560	s.	40	w.	3	13	6	11	5.0	
Macon	370	78	87	29.69	30.09	+ .06	63.8	+ 0.7	87	22	74	35	10	53	37	.....	.....	.....	.....	4.30	+ 0.9	10	5,123	s.	27	nw.	3	15	3	12	4.7	
Thomasville	273	8	57	29.79	30.09	+ .06	66.8	+ 0.1	88	19	78	37	10	56	39	60	57	78	4.72	+ 1.1	12	4,307	e.	24	sw.	23	16	3	11	4.3	
Pensacola	56	79	96	30.01	30.07	+ .05	66.5	— 1.2	80	23	73	44	14	60	24	.....	.....	.....	.....	4.17	+ 1.0	9	8,338	se.	46	sw.	30	11	5	14	5.3	
Anniston	741	9	57	29.30	30.09	+ .06	61.4	+ 1.0	85	18	73	35	10	50	38	.....	.....	.....	.....	12.15	+ 8.5	10	4,997	se.	31	sw.	13	9	4	17	6.2	
Birmingham	700	11	48	29.31	30.08	+ .06	63.1	— 0.4	85	18	73	37	9	54	34	55	50	70	10.31	+ 6.6	9	6,296	s.	37	se.	12	11	14	5	4.5	
Mobile	57	98	106	30.00	30.06	+ .04	66.4	+ 0.4	84	23	74	43	14	59	29	61	58	78	9.04	+ 4.7	9	6,960	se.	37	sw.	30	10	11	9	5.1	
Montgomery	223	100	112	29.83	30.08	+ .05	64.6	— 0.6	87	18	75	39	10	54	33	57	52	70	7.40	+ 3.2	7	4,779	se.	27	sw.	4	12	9	9	4.5	
Meridian	375	84	93	29.64	30.04	+ .02	63.2	— 0.9	86	29	74	35	14	52	38	57	52	72	8.85	+ 3.8	10	4,911	s.	32	sw.	12	11	8	11	5.1	
Vicksburg	247	62	74	29.76	30.04	+ .04	65.6	+ 0.4	85	29	75	44	9	57	27	58	52	68	6.25	+ 1.1	11	5,959	s.	42	nw.	12	13	8	9	4.8	
New Orleans	51	90	121	29.99	30.04	+ .04	69.0	+ 1.1	86	25	77	46	14	61	24	63	60	79	8.08	+ 3.2	9	7,756	se.	37	se.	12	9	10	11	5.3	
West Gulf States.							64.5	— 1.0											71	2.50	— 1.0								4.6	
Shreveport	249	77	84	29.74	30.01	+ .04	64.4	— 1.4	86	6	74	39	9	55	30	58	53	71	3.39	— 1.2	9	6,310	se.	33	se.	12	10	9	11	5.2	
Bentonville	960	11	44	28.60	29.98	+ .02	56.2	— 0.7	82	29	68	30	13	44	35	.....	.....	.....	.....	3.49	— 0.4	10	6,797	s.	44	s.	6	15	7	8	4.5	T.
Fort Smith	457	168	94	29.49	29.97	+ .01	60.6	— 1.1	85	29	72	37	9	50	40	51	43	59	2.53	— 1.4	10	7,527	e.	47	sw.	6	14	10	6	4.4	
Little Rock	357	139	147	29.62	29.99	+ .01	61.7	— 1.0	83	28	71	37	9	52	30	54	47	63	4.23	— 0.3	11	8,553	s.	50	nw.	29	14	11	5	4.0	
Brownsville	57	4	....	.....	.....	.....	.....	.....	100	30	....	46	2	.....	.....	.....	.....	.....	.....	0.78	.....	..	.....	s.	.....	.....	.....	.....	.....	.....	.....	.....
Corpus Christi	20	69	77	29.94	29.96	+ .01	70.6	— 0.3	95	6	76	48	10	65	28	65	62	80	0.86	— 0.9	3	13,228	se.	55	ne.	7	10	12	8	5.1	
Fort Worth	670	106	114	29.27	29.98	+ .04	64.2	— 1.1	97	29	76	33	9	52	40	.....	.....	.....	.....	1.66	— 1.0	4	10,301	s.	48	nw.	20	18	7	5	3.4	
Galveston	54	106	112	29.96	30.02	+ .05	67.8	— 0.9	82	30	72	51	9	64	18	64	62	84	3.39	+ 0.3	7	9,297	se.	46	n.	7	12	12	6	4.5	
Palestine	510	73	79	29.46	29.99	+ .03	64.6	— 1.3	84	6	74	40	9	55	34	58	55	76	2.51	— 1.6	7	7,272	s.	32	sw.	12	10	8	12	5.7	
San Antonio	701	80	191	29.21	29.94	+ .01	68.8	— 0.2	98	29	80	42	2	58	42	58	50	62	0.82	— 2.1	3	6,184	se.	33	n.	8	13	10	7	4.5	
Taylor	583	55	63	29.37	29.98	+ .03	66.0	— 1.5	92	29	77	38	10	55	40	.....	.....	.....	.....	2.08	— 1.9	9	8,413	s.	34	s.	20	14	9	7	4.5	
Ohio Val. and Tenn.							54.8	— 0.2											65	5.09	+ 1.4								5.6	
Chattanooga	762	106	112	29.26	30.08	+ .05	60.6	+ 0.6	85	18	71	35	10	51	36	52	46	62	6.22	+ 0.8	10	5,242	s.	42	sw.	13	11	4	15	5.5	
Knoxville	996	93	100	28.99	30.04	+ .01	58.8	+ 1.4	86	18	69	34	11	49	31	50	43	62	5.70	+ 1.1	12	4,939	sw.	48	sw.	30	13	7	10	5.2	T.
Memphis	399	76	97	29.61	30.04	+ .04	61.8	0.0	83	18	71	39	9	53	29	53	46	61	6.49	+ 1.7	11	7,676	s.	48	w.	6	13	5	12	5.0	
Nashville	546	168	191	29.46	30.05	+ .04	59.2	+ 0.1	84	18	70	32	9	49	38	53	48	69	4.12	— 0.2	12	9,502	s.	54	s.	19	11	9	10	5.3	
Lexington	989	75	102	28.97	30.05	+ .03	53.9	+ 0.2	83	18	64	25	10	43	39	.....	.....	.....	.....	6.72	+ 3.4	12	9,504	sw.	64	sw.	29	15	6	9	4.7	T.
Louisville	525	111	132	29.45	30.04	+ .03	55.9	— 0.1	84	18	66	29	10	46	39	49	43	66	5.86	+ 1.8	11	7,501	s.	46	w.	30	8	10	12	6.0	
Evansville	431	72	82	29.54	30.01	+ .01	55.4	— 1.0	80	29	65	29	10	46	33	.....	.....	.....	.....	5.21	+ 1.8	10	7,608	s.	50	s.	29	9	16	5	5.2	
Indianapolis	822	154	164	29.10	30.00	.00	50.7	— 1.7	79	18	60	25	10	41	30	44	38	65	4.18	+ 0.7	11	9,699	s.	56	s.	12	7	9	14	6.5	T.
Cincinnati	628	152	160	29.34	30.02	+ .01	53.4	— 0.9	84	18	64	25	10	43	33	46	38	58	3.62	+ 0.7	12	6,103	se.	33	w.	30	5	12	13	6.3	0.1
Columbus	824	173	222	29.13	30.02	.00	50.1	— 0.9	82	29	61	22	10	39	39	44	37	65	3.20	+ 0.3	11	10,825	se.	60	nw.	7	7	10	13	6.5	0.4
Pittsburg	842	336	352	29.12	30.03	+ .01	50.0	— 1.0	30	18	59	22	10	41	33	44	37	64	5.23	+ 2.3	15	8,389	w.	68	w.	7	2	17	11	6.7	0.8
Parkersburg	638	77	84	29.38	30.04	+ .01	53.3	— 0.3	86	29	64	26	10	42	39	47	42	70	4.24	+ 1.3	14	5,616	se.	48	w.	7	10	12	8	5.1	0.2
Elkins	1,940	41	50	27.99	30.06	+ .03	49.8	+ 1.1	83	18	62	14	11	38	47	44	38	69	5.39	+ 2.1	18	3,442	w.	30	w.	7	9	12	9	5.4	4.8
Lower Lake Region.							43.6	— 1.1											72	3.64	+ 1.3								6.6	
Buffalo	767	178	206	29.16	29.99	— .02	41.8	— 0.5	68	13	50	16	11	34	33	38	35	78	4.59	+ 2.1	16	11,842	sw.	75	sw.	7	4	12	14	6.7	6.4
Canton	448	10	71	29.54	30.03	.....	39.8	— 2.7	72	13	48	17	10	31	31	.....	.....	.....	.....	3.39	+ 1.1	18	9,881	w.	65	w	8	3	10	17	7.1	5.8
Oswego	335	76	91	29.64	30.02	+ .01	41.6	— 1.6	74	6	50	21	10	34	35	38	34	77	3.26	+ 1.0	13	9,751	s.	50	s.	13	7	8	15	6.6	4.9
Rochester	523	86	102	29.45	30.03	+ .02	43.8	— 0.1	73	5	53	17	11	35	33	38	33	71	3.54	+ 1.1	17	7,308	w.	58	w.	7	5	7	18	7.0	9.8
Syracuse	597	97	113	29.38	30.03	+ .02	42.5	— 1.9	75	19	51	19	11	34	38	.....	.....	.....	.....	3.09	+ 0.8	16	11,404	s.	58	s.	13	4	9	17	7.2	5.5
Erie	714	92	102	29.22	30.00	— .02	44.9	+ 0.2	77	18	54	17	11	36	38	39	33	68	5.15	+ 2.8	15	9,814	s.	45	se.	30	8	5	17	6.5	8.9
Cleveland	762	190	201	29.17	30.00	— .02	45.9	— 0.1	79	18	55	22	10	37	37	40	35	67	3.41	+ 1.1	13	12,037	se.	66	w.	21	7	11	12	6.1	1.8
Sandusky	229	62	70	29.29	29.98	— .04	46.4	— 0.9	80	18	55	23	10	38	33	.....	.....	.....	.....	2.59	0.0	11	7,765	sw.	40	w.	7	5	12	13	6.3	0.2
Toledo	628	207	246	29.30	30.00	— .01	46.0	— 1.3	79	18	56	21	10	36	34	41	36	70	3.19	+ 0.9	14	13,947	sw.	70	sw.	7	9	12	9	5.9	0.1
Detroit	730	218	258	29.19	30.00	— .02	43.4	— 2.1	74	18	53	21	10	34	33	39	24	73	4.25	+ 1.9	13	12,335	e.	70	sw.	7	6	11	13	6.6	3.0

TABLE I.—*Climatological data for U. S. Weather Bureau stations, April, 1909*—Continued.

Stations.	Elevation of instruments.			Pressure, in inches.			Temperature of the air, in degrees Fahrenheit.										Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity, per cent.	Precipitation, in inches.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness during daylight, tenths.	Total snowfall.
	Barometer above sea level, feet.	Thermometers above ground.	Anemometer above ground.	Actual, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hrs.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with .01, or more.	Total movement miles.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.					
Upper Lake Region.																														
Alpena	609	13	92	29.29	29.97	— .05	37.5	— 2.9											77	4.77	+ 2.7								6.8	
Escanaba	612	40	82	29.30	29.98	— .04	36.6	— 1.4	62	5	44	11	10	29	26	33	30	80	4.05	+ 1.8	16	9,847	se.	52	w.	7	5	9	16	7.0	13.7
Grand Haven	632	54	92	29.25	29.95	— .06	33.8	— 3.4	50	5	40	12	10	28	21	31	27	77	4.81	+ 2.7	19	7,817	s.	45	e.	29	5	9	16	6.9	26.9
Grand Rapids	707	127	162	29.18	29.96	— .06	40.8	— 3.2	70	6	48	18	10	33	28	38	36	84	8.43	+ 6.0	19	9,833	e.	48	sw.	7	7	10	13	6.3	3.1
Houghton	668	66	74	29.22	29.96	— .06	42.8	— 3.4	72	5	52	19	10	34	32	38	34	76	8.29	+ 5.8	18	10,140	w.	52	sw.	2	6	12	16	7.3	2.9
Marquette	734	77	116	29.16	29.98	— .04	32.8	— 4.1	58	20	40	6	10	26	31	.....	.....	.....	2.04	0.0	11	5,455	e.	30	se.	30	7	11	12	6.3	17.4
Port Huron	638	70	120	29.28	29.99	— .03	33.0	— 4.5	53	20	39	13	10	27	26	30	24	71	3.39	+ 1.4	18	7,720	nw.	54	s.	11	6	11	13	6.3	27.6
Sault Sainte Marie	614	40	61	29.27	29.99	— .04	41.4	— 0.8	71	18	50	19	10	32	32	37	33	76	4.39	+ 2.3	14	9,815	s.	54	w.	7	5	9	16	7.1	8.0
Chicago	823	140	310	29.06	29.96	— .04	33.0	— 2.7	50	1	40	6	10	26	28	30	27	81	3.30	+ 1.2	14	7,849	nw.	40	w.	27	3	4	23	8.0	9.6
Milwaukee	681	122	139	29.21	29.97	— .02	45.0	— 0.9	74	5	52	25	10	38	29	40	36	74	7.73	+ 4.8	16	12,556	se.	60	w.	7	3	14	13	6.6	0.3
Green Bay	617	49	86	29.26	29.93	— .08	40.5	— 1.3	73	5	47	23	10	34	35	37	33	80	7.09	+ 4.4	19	9,971	w.	65	ne.	29	7	12	11	5.8	1.4
Duluth	1,133	11	47	28.71	29.96	— .05	38.3	— 2.4	59	5	36	46	18	31	27	34	29	74	4.00	+ 1.6	19	8,415	ne.	58	nw.	7	4	5	21	7.8	4.3
North Dakota.							32.0	— 6.4	58	20	40	8	9	24	25	29	25	78	2.15	0.0	13	10,673	ne.	60	ne.	29	6	11	13	6.5	12.6
Moorhead	940	8	57	28.95	29.99	.00	54.3	— 6.4										74	0.39	— 1.0									5.7	
Bismarck	1,674	8	57	28.18	30.01	+ .04	35.2	— 6.2	69	26	46	12	27	25	51	32	29	84	1.45	— 0.9	15	7,892	nw.	38	nw.	26	12	8	10	5.3	7.2
Devils Lake	1,482	11	44	28.35	29.96	— .03	35.2	— 7.4	65	25	47	11	13	23	37	30	24	68	0.84	— 1.0	9	9,933	nw.	52	nw.	2	6	12	12	6.1	7.4
Williston	1,872	14	56	.....	29.97	+ .01	32.6	— 5.6	62	25	42	13	27	23	39	28	22	71	0.64	— 1.4	12	10,612	nw.	48	nw.	30	9	12	9	5.7	5.0
Upper Miss. Valley.							34.1	— 6.4	62	25	45	9	13	23	39	.....	.....	.....	0.64	— 0.6	7	9,048	nw.	49	w.	1	9	8	13	.....	0.8
Minneapolis	.....	102	208	.....	.....	.....	46.9	— 3.6										68	3.40	+ 2.4									6.1	
St. Paul	837	171	179	29.02	29.94	— .05	38.5	.....	65	26	47	18	9	30	34	.....	.....	.....	2.24	— 0.2	10	10,529	w.	52	w.	7	8	9	13	6.0	8.5
La Crosse	714	11	48	29.16	29.95	— .03	38.6	— 7.1	65	17	46	18	9	31	29	34	27	65	2.42	+ 0.1	11	9,529	nw.	50	nw.	7	6	19	5	5.5	10.8
Madison	974	70	78	28.87	29.94	— .05	40.5	— 6.8	67	17	48	19	10	33	28	.....	.....	.....	5.96	+ 3.7	16	5,289	nw.	32	nw.	7	2	14	14	7.1	10.8
Charles City	1,015	10	49	28.85	29.95	— .03	40.5	— 4.0	70	5	48	22	10	33	33	36	31	72	7.19	+ 4.8	16	9,012	nw.	51	s.	11	7	7	16	7.0	0.8
Davenport	606	71	79	29.27	29.93	— .05	40.2	— 6.1	68	17	49	20	10	32	32	36	33	78	5.42	+ 2.6	16	7,211	nw.	36	s.	11	3	12	15	7.4	7.8
Des Moines	861	84	101	29.01	29.92	— .05	46.8	— 3.4	81	29	57	22	10	37	41	41	36	69	6.02	+ 3.1	17	7,765	nw.	46	nw.	29	10	6	14	6.0	T.
Dubuque	698	100	117	29.19	29.95	— .03	45.1	— 5.5	76	26	55	24	10	36	34	40	34	69	5.14	+ 2.2	15	8,115	nw.	53	sw.	11	3	10	17	7.1	T.
Keokuk	614	64	78	29.28	29.96	— .02	48.4	— 5.5	66	17	52	21	10	35	29	38	33	69	7.40	— 4.5	18	6,723	nw.	39	nw.	7	7	10	13	6.3	1.7
Cairo	356	87	93	29.63	30.02	+ .03	50.6	— 1.4	85	29	61	25	10	40	39	43	37	67	4.99	+ 1.6	11	7,745	se.	40	w.	29	12	9	9	4.8	T.
La Salle	536	56	64	29.40	29.98	— .01	57.6	— 0.7	81	17	67	34	10	48	30	50	42	61	4.85	+ 1.3	9	8,930	s.	42	s.	12	9	12	9	5.5	
Peoria	609	11	45	29.29	29.96	— .03	47.3	— 2.5	84	29	57	22	10	37	46	.....	.....	.....	5.93	+ 2.8	15	8,667	w.	60	sw.	6	6	9	15	6.7	0.2
Springfield, Ill	644	10	91	29.26	29.95	— .03	48.4	— 2.5	85	29	59	21	10	38	43	42	37	68	7.17	+ 3.9	14	8,644	s.	49	w.	6	7	12	11	5.6	T.
Hannibal	534	75	109	29.38	29.96	— .02	51.6	— 0.4	85	29	62	25	10	41	35	45	39	66	5.34	+ 2.0	12	8,774	s.	40	s.	11	9	10	11	5.8	T.
St. Louis	567	208	217	29.35	29.96	— .02	51.7	— 1.9	88	29	63	26	9	41	39	.....	.....	.....	4.78	+ 1.5	11	9,455	sw.	44	s.	11	8	8	14	5.9	T.
Missouri Valley.							54.2	— 1.9	85	29	64	29	10	44	34	46	39	59	6.18	+ 2.7	11	9,954	s.	41	sw.	6	12	9	9	5.1	
Columbia, Mo	784	11	84	29.10	29.94	— .04	46.9	— 3.6										61	2.19	+ 0.7									5.6	
Kansas City	963	116	181	28.89	29.93	— .03	53.0	— 1.3	88	29	66	27	9	41	40	.....	.....	.....	3.35	— 0.4	13	8,452	s.	52	sw.	6	10	12	8	4.9	
Springfield, Mo	1,324	98	104	28.56	29.96	— .01	52.6	— 1.7	84	4	64	31	10	42	40	45	39	65	4.20	+ 0.9	12	11,977	s.	50	s.	29	11	13	6	4.9	T.
Iola	984	11	50	28.90	29.95	.00	54.2	— 1.5	84	29	66	30	13	43	37	46	38	62	4.09	+ 0.2	8	10,437	s.	48	w.	6	17	6	7	4.3	0.2
Topeka	.....	85	101	.....	.....	.....	54.6	— 0.4	86	29	67	29	13	42	44	.....	.....	.....	4.19	+ 1.4	9	8,526	s.	40	sw.	11	7	14	9	5.7	
Lincoln	1,189	11	84	28.65	29.93	— .01	52.1	— 1.6	86	4	64	30	13	40	40	.....	.....	.....	1.61	— 1.1	6	9,943	s.	54	s.	11	15	11	4	3.9	T.
Omaha	1,105	115	121	28.74	29.94	— .01	46.4	— 3.3	87	17	59	23	8	34	47	39	31	62	1.08	— 1.7	12	10,297	n.	60	nw.	28	6	13	11	6.2	T.
Valentine	2,598	47	54	27.22	29.97	+ .03	45.6	— 4.9	83	26	56	26	8	36	37	39	32	64	1.34	— 1.7	10	8,790	n.	48	nw.	26	6	7	17	7.2	1.3
Sioux City	1,135	96	164	28.73	29.96	+ .01	40.0	— 5.4	80	17	53	13	8	27	44	33	24	62	1.35	— 1.0	12	8,587	nw.	44	nw.	30	9	17	4	5.0	7.5
Pierre	1,572	70	75	28.28	29.97	+ .02	41.8	— 6.7	77	26	52	24	8	32	38	36	29	63	2.09	— 0.7	12	11,353	nw.	56	nw.	28	5	10	15	6.9	3.8
Huron	1,306	56	67	28.57	29.99	+ .03	41.6	— 4.9	76	17	53	17	1	30	45	33	22	51	0.68	— 1.3	11	9,469	nw.	48	nw.	30	7	15	8	5.8	1.5
Yankton	1,233	49	57	28.62	29.96	+ .01	39.2	— 5.4	78	17	51	16	13	27	44	33	25	62	0.61	— 2.0	7	10,264	nw.	49	nw.	2	9	9	12	5.8	0.7
Northern Slope.							41.6	— 5.8	77	26	53	22	13	31	41	.....	.....	.....	1.74	— 1.1	10	8,026	ne.	42	w.	2	3	16	11	6.7	4.2
Havre	2,505	11	44	27.32	30.01	+ .08	37.4	— 5.4										66	1.02	— 0.6									5.9	
Miles City	2,371	26	48	27.44	30.02	+ .06	35.4	— 7.3	64	25	47	12	30	24	36	31	26	73	0.92	— 0.1	8	6,556	nw.	34	nw.	25	10	15	5	4.8	9.1
Helena	4,110	8	56	25.76	30.02	+ .05	39.4	— 5.3	70	25	52	12	12	27	39	33	27	67	1.15	0.0	10	5,198	nw.	29	nw.	6	7	18	5	5.0	6.5
Kalispell	2,962	11	34	26.90	30.00	+ .04	35.9	— 6.1	62	9	46	13	30	26	31	31	25	66	1.33	+ 0.2	9	5,939	w.	35	w.	13	5	6	19	7.2	17.8
Rapid City	3,234	46	50	26.52	29.99	+ .04	38.6	— 3.9	61	9	49	21	30	28	32	32	25	63	0.83	— 0.2	8	4,448	w.	27	sw.	16	5	15	10	5.7	3.7
Cheyenne	6,088	56	64	23.90	29.95	+ .04	38.8	— 4.7	70	25	50	20	30	27	37	32	23	59	0.45	— 1.8	10	6,386	nw.	37	sw.	3	3	15	12	6.5	1.9
Lander	5,372	26	36	24.56	29.96	+ .02	36.0	— 5.6	70	17	48	10	30	24	36	30	24	66	0.97	— 0.9	10	8,366	nw.	42	nw.	30	8	15	7	5.1	9.6
Sheridan	3,790	9	47	26.04	30.01	.....	37.2	— 5.0	68	17	50	6	30	24	40	30	21	57	2.01	— 0.4	8	3,808	sw.	34	sw.	3	8	16	6	5.1	20.1
Yellowstone Park	6,200	11	48	23.78	29.99	+ .03	37.0	.....	67	25	49	16	12	25	41	31	25	63	1.79	.....	17	6,386	nw.	48	nw.	17	3	11	16	6.4	16.0
North Platte	2,821	11	51	27.01	29.96	+ .04	30.8	— 6.2	53	25	41	4	7	20	32	25	19	65	0.81	— 0.6	11	6,068	nw.	31	nw.	17	5	3	22	7.7	8.8
Middle Slope.							44.3	— 4.7	81	17	58	21	8	31	43	37	31	70	0.72	— 1.4	6	7,305	nw.	48	nw.	28	10	12	8	5.2	4.3
Denver	5,291	129	136	21.64	29.93	+ .03	50.6	— 3.1										58	1.62	— 0.6									4.7	
Leadville	10,242	7	.....	.....	.....	.....	43.2	— 4.5	76	17	56	14	8	31	37	34	25	59	2.59	+ 0.4	11	5,901	sw.	44	n.	29	10	13	7	4.9	25.4
Pueblo	4,685	80	86	25.20	29.89	+ .01	46.4	— 4.1	81	17	60	17	8	32	47	37	27	56	1.52	+ 0.1	10	6,523	se.	43	w.	28	12	13	5	4.3	12.2
Concordia	1,398	42	50	28.45	29.93	.00	49.6	— 4.0	92	28	62	25	8	37	47	42	35	64	1.58	— 0.8	9	7,331	n.	36	s.	10	7	20	3	4.9	1.8
Dodge City	2,509	44	54	27.30	29.91	+ .01	51.4	— 3.0	93	17	66	27	30	37	45	41	32	58	0.02	— 1.8	1	8,692	nw.	41	se.	17	17	10	3	3.8	T.
Wichita	1,358	98	121	28.51	29.93	+ .02	54.8	— 1.8	91	4	67	31	13	42	39	45	36	56	1.59	— 1.1	5	10,957	s.	43	sw.	11	10	12	8	4.8	
Oklahoma	1,214	10	47	28.65	29.93	+ .01	58.4	— 1.2	90	18	70	31	13	46	40	49	40	58	2.44	— 0.4	6	15,961	s.	70	n.	25	12	10	8	4.8	
Southern Slope.							61.9	— 0.5										47	0.41	— 1.4									3.5	
Abilene	1,738	45	54	28.13	29.92	+ .02	63.8	— 0.6	94	28	77	30	9	51	38	51	38	49	0.38	— 1.9	3	8,388	s.	44	w.	12	13	10	7	4.4	
Amarillo	3,676	10	49	26.19	29.90	+ .03	54.0	— 0.6	89	17	70	26	1	38	45	42	32	54	0.50	— 1.2	5	10,794	s.	46	w.	29	24	5	1	3.2	1.6
Del Rio	944	8	57	28.95	29.92	+ .03	70.8	+ 0.8	103	29	84	38	1	58	47	.....	.....	.....	0.75	— 2.2	2	7,346	se.	42	nw.	26	17	11	2	3.7	
Roswell	3,578	9	57	26.28	29.88	+ .03	58.9	— 1.7	92	17	77	23	9	41	54	43	26	38	0.00	— 0.5	0	6,839	sw.	42	n.	7	21	9	0	2.6	
Southern Plateau.							56.9	— 0.9										35	0.12	— 0.5									1.6	
El Paso	3,762	110	133	26.12	29.84	+ .01	62.9	— 0.9	86	17	76	35	9	50	39	43	15	20	0.00	— 0.2	0	10,780	w.	60	w.	5	24	6	0	1.4	
Santa Fe	7,013	8	56	23.17	29.87	+ .03	44.1	— 3.5	71	16	58	12	8	31	37	34	21	44	0.30	— 0.6	4	8,012	sw.	51	sw.	11	18	11	1	3.0	2.2
Flagstaff	6,907	8	57	25.29	29.86	+ .02	42.4	+ 0.2	69	14	58	19	7	27	44	32	18	45	0.26	— 1.4	4	7,869	sw.	47	sw.	4	21	5	4	2.3	2.6
Phoenix	1,108	50	56	28.73	29.87	.00	67.0	+ 0.4	94	27	82	38	6	52	43	49	27	28	0.07	— 0.4	1	3,836	e.	23	sw.	19	26	4	0	1.1	
Yuma	141	9	58	29.74	29.89	.00	69.0	— 1.1	98	26	87	43	6	51	47	52	36	36	0.00	— 0.1	0	5,888	w.	37	n.	7	30	0	0	0.3	
Brawley	†105	11	31	30.01	29.90	.....	69.6	.....	99	27	86	46	10	53	43	53	37	37	0.00	.....	0	6,453	w.	36	w.	28	26	4	0	1.2	
Independence	3,910	11	42	25.96	29.93	+ .03	56.2	— 0.5	81	26	72	28	6	41	40	43	26	35	0.12	— 0.5	1	6,424	n.	36	n.	21	25	5	0	1.7	
Middle Plateau.							46.2	— 1.6										47	0.62	— 0.7									3.8	
Reno	4,532	56	63	25.48	30.01	+ .04	48.8	+ 1.5	75	25	64	25	11	33	42	37	24	45	0.18	— 0.4	1	4,872	w.	29	w.	3	18	10	2	2.7	
Tonopah	6,090	12	26	24.04	29.89	.....	47.4	+ 3.9	70	16	59	23	5	36	29	35	18	34	0.06	— 1.6	2	9,493	w.	54	nw.	29	14	15	1	3.1	
Winnemucca	4,344	18	56	25.63	30.04	+ .08	45.7	— 1.4	74	25	62	19	7	29	41	35	23	51	0.40	— 0.5	4	4,671	sw.	33	w.	3	21	6	3	2.7	0.4
Modena	5,479	10	43	24.56	29.92	+ .04	44.6	— 2.3	73	16	60	18	8	30	42	36	28	55	0.19	— 1.5	5	8,738	nw.	44	sw.	10	15	10	5	3.8	0.2
Salt Lake City	4,360	105	110	25.57	29.96	+ .04	45.8	— 4.3	70	17	56	26	5	36	31	37	25	47	1.60	— 0.7	11	5,369	nw.	37	nw.	10	15	8	7	4.5	3.4
Durango	6,546	18	56	23.56	29.87	+ .02	42.8	— 3.6	72	16	57	14	8	29	39	32	21	50	0.79	— 0.4	7	5,250	nw.	36	w.	28	10	17	3	4.4	1.0
Grand Junction	4,608	43	51	25.30	29.88	.00	48.4	— 4.8	78	16	62	19	6	35	39	38	26	50	1.14	+ 0.5	9	4,434	nw.	30	nw.	4	11	7	12	5.4	1.0
Northern Plateau.							46.0	— 2.9										52	0.54	— 0.8									5.6	
Baker City	3,471	48	58	26.47	30.09	+ .09	41.4	— 2.1	64	9	53	21	18	30	37	36	28	61	0.25	— 0.7	6	5,334	nw.	27	nw.	3	9	14	7	4.6	2.1
Boise	2,739	72	86	27.19	30.07	+ .09	46.2	— 3.9	69	25	58	23	4	35	34	37	24	44	0.15	— 1.0	1	5,334	nw.	29	nw.	29	8	16	6	5.0	T.
Lewiston	757	16	51	29.27	30.08	+ .09	50.1	— 2.8	71	8	61	28	18	39	38	.....	.....	.....	0.75	— 0.4	6	6,425	w.	40	w.	9	6	8	16	6.4	T.
Pocatello	4,477	46	84	25.43	29.97	+ .03	42.7	— 4.1	67	25	53	18	30	32	37	35	26	54	0.55	— 1.5	8	7,938	s.	44	sw.	3	12	9	9	5.4	4.1
Spokane	1,929	101	110	27.98	30.05	+ .06	45.0	— 2.7	67	8	56	24	18	34	37	36	24	48	0.44	— 0.8	4	6,141	sw.	30	sw.	16	5	5	20	6.9	T
Walla Walla	1,000	71	79	29.03	30.11	+ .10	50.8	— 2.0	71	8	61	33	8	41	38	42	30	51	1.09	— 0.6	6	5,503	s.	36	sw.	9	10	16	4	4.9	T.
N. Pac. Coast Reg.							47.4	— 1.0										74	0.92	— 2.4									5.4	
Blaine	58	4	....	30.04	30.10	.....	.....	.....	61	30	...	28	7	...	...	...	...	...	0.91	.....	...	.....	w.	.....	.....	.....	.....	.....	.....	.....	.....
North Head	211	11	56	30.01	30.24	+ .19	46.6	— 0.9	70	8	50	39	3	43	22	44	42	85	1.51	— 1.7	12	10,630	nw.	52	nw.	9	7	10	13	6.3	
Port Crescent	259	8	53	29.93	30.21	+ .29	42.3	— 2.4	57	8	50	27	18	34	29	..	....	...	0.33	— 2.2	5	4,278	nw.	16	nw.	12	8	18	4	5.0	

TABLE I.—*Climatological data for U. S. Weather Bureau stations, April, 1909*—Continued.

Stations.	Elevation of instruments.			Pressure, in inches.			Temperature of the air, in degrees Fahrenheit.								Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity, per cent.	Precipitation, in inches.			Wind.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness during daylight, tenths.	Total snowfall.
	Barometer above sea level, feet.	Thermometers above ground.	Anemometer above ground.	Actual, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hrs.	Departure from normal.	Mean max. + mean min. ÷ 2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.				Total.	Departure from normal.	Days with .01, or more.	Total movement, miles.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.				
N. P. Coast Reg.—Cont.																													
Seattle	123	185	224	30.08	30.22	+ .19	47.7	— 1.7	67	8	55	37	7	40	26	43	39	75	0.77	— 1.9	12	5,892	s.	28	s.	9	6	11	13	6.8	
Tacoma	213	113	120	29.96	30.20	+ .17	47.3	— 1.6	68	8	56	33	7	39	31	43	38	73	0.74	— 2.0	8	4,981	sw.	31	sw.	5	8	11	11	5.3	
Tatoosh Island	86	7	57	30.10	30.20	+ .20	46.0	— 0.1	55	8	50	37	3	42	14	42	39	80	1.86	— 4.4	12	9,700	w.	43	w.	5	7	14	9	5.6	
Portland, Oreg.	153	63	106	30.05	30.21	+ .15	51.0	— 0.2	78	8	60	36	17	42	35	45	38	67	0.89	— 2.2	7	4,326	nw.	25	nw.	3	7	12	11	5.7	T.
Roseburg	510	9	57	29.65	30.21	+ .14	50.9	.00	78	8	64	30	7	38	43	44	36	63	0.37	— 2.1	4	2,630	nw.	17	nw.	30	10	19	1	3.4	
Mid. Pac. Coast Reg.							57.1	+ 1.7										63	0.04	— 1.9									2.4	
Eureka	62	62	80	30.12	30.19	+ .08	48.3	— 1.2	68	8	53	38	29	44	23	45	42	80	0.24	— 3.7	1	7,422	n.	37	n.	10	21	6	3	3.2	
Mount Tamalpais	2,375	11	18	27.58	30.06	+ .01	55.1	.....	76	30	63	34	4	47	25	47	41	62	T.	— 2.0	0	12,152	nw.	84	nw.	27	24	5	1	1.8	
Point Reyes Light	490	7	18	29.50	30.02	.....	51.6	.....	75	8	57	43	25	46	27	....	....	....	T	.....	0	19,071	nw.	93	nw.	3	18	5	7	3.7	
Red Bluff	332	50	56	29.67	30.02	— .01	62.5	+ 3.4	86	16	75	42	6	50	36	49	35	42	0.03	— 1.8	1	4,986	nw.	24	n.	29	28	2	0	0.9	
Sacramento	69	106	117	29.94	30.01	.00	61.2	+ 3.2	84	26	73	43	11	50	29	52	44	58	T.	— 2.0	0	6,016	nw.	34	nw.	21	22	7	1	1.9	
San Francisco	155	200	204	29.89	30.06	+ .01	56.6	+ 2.9	80	30	65	44	4	48	27	49	44	72	T.	— 1.8	0	5,969	w.	32	w.	10	21	8	1	2.4	
San Jose	141	12	110	29.90	30.05	.....	57.1	+ 0.4	85	30	72	36	4	42	41	....	....	....	0.00	0.0	0	4,311	nw.	24	w.	19	27	2	1	1.5	
Southeast Farallon	30	9	17	30.04	30.07	.....	50.8	.....	71	8	53	46	26	49	19	....	....	....	0.00	— 1.9	0	15,087	nw.	60	n.	4	18	6	6	3.4	
S. Pac. Coast Reg.							59.8	+ 1.6										67	0.01	— 1.0									3.2	
Fresno	330	67	70	29.66	30.02	+ .03	62.6	+ 1.4	89	25	77	40	4	48	37	52	43	56	T.	— 0.7	0	3,890	nw.	24	w.	27	27	3	0	1.5	
Los Angeles	338	159	191	29.64	30.01	+ .02	60.6	+ 3.0	89	2	69	46	13	52	28	52	46	68	T.	— 1.1	0	4,406	sw.	24	sw.	5	12	14	4	3.9	
San Diego	87	94	102	29.92	30.01	.....	59.0	+ 0.8	82	2	66	46	12	52	28	52	47	70	0.02	— 0.7	1	4,599	nw.	20	nw.	25	17	5	8	3.7	
San Luis Obispo	201	47	54	29.85	30.06	.....	56.2	+ 1.0	85	9	67	38	22	46	38	50	46	76	0.03	— 1.4	1	4,027	nw.	24	w.	19	18	8	4	3.6	
West Indies.																															
Grand Turk	11	6	20	30.05	30.06	+ .05	78.5	.....	87	28	84	68	5	72	....	....	....	....	1.69	.....	11	.....	e.	....	....	....	....	....	....	....	
San Juan	82	48	90	29.94	30.02	+ .04	76.6	.....	85	29	82	67	8	71	14	72	69	77	2.77	— 0.8	16	9,326	e.	34	e.	16	15	12	3	4.1	
Panama.																															
Christobal	17	5	60	29.86	29.88	.....	80.1	.....	86	24	84	72	14	77	13	76	74	83	3.56	.....	18	8,659	n.	27	ne.	4	10	12	8	5.0	
Culebra	....	....	....	29.48	29.90	.....	79.9	.....	94	15	89	67	15	71	27	74	72	86	2.56	.....	10	6,194	nw.	31	n.	11	4	16	10	6.0	
Bas Obispo	172	4	30	29.67	29.88	.....	78.9	.....	91	18	87	65	11	70	25	74	73	91	5.90	.....	12	3,405	nw.	21	nw.	15	0	24	6	7.0	
Ancon	92	6	69	29.77	29.86	.....	81.4	.....	95	8	90	71	13	73	22	75	73	86	2.92	.....	8	6,103	nw.	23	n.	4	0	18	12	7.0	
Alhajuela	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	3.54	.....	13	.....	.....	.....	.....	.....	.....	.....	.....	.....	
Bohio	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	7.23	.....	19	.....	.....	.....	.....	.....	.....	.....	.....	.....	
Gatun	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4.03	.....	17	.....	.....	.....	.....	.....	.....	.....	.....	.....	

† Below sea level.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for storms in which the rate of fall equaled or exceeded 0.25 in any 5 minutes, or 0.80 inch in 1 hour, during April, 1909, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration. From—	Total duration. To—	Total amount of precipitation.	Excessive rate. Began—	Excessive rate. Ended—	Amount before excessive began.	Depths of precipitation (in inches) during periods of time indicated. 5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex. †	20	.....	.....	0.35	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Albany, N. Y.	14	.....	.....	0.59	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.17	.....	.....	.....
Alpena, Mich.	6	.....	.....	0.50	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.23	.....	.....	.....
Amarillo, Tex.	20	.....	.....	0.18	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.18	.....	.....	.....
Anniston, Ala.	22	5:25 p. m.	10:30 p. m.	3.34	5:34 p. m.	6:44 p. m.	0.02	0.24	0.36	0.64	1.07	1.42	1.67	1.95	2.09	2.17	2.29	2.56	2.84	.....	.....
Do	23	D. N.	D. N.	1.21	3:47 a. m.	4:26 a. m.	0.17	0.08	0.12	0.16	0.23	0.31	0.43	0.83	0.94	.....	.....	.....	.....	.....	.....
Do	30	3:45 p. m.	8:55 p. m.	2.17	6:26 p. m.	7:16 p. m.	0.04	0.26	0.59	0.82	0.96	1.09	1.37	1.51	1.61	1.70	1.77	.....	.....	.....	.....
Asheville, N. C.	30	9:53 a. m.	1:08 p. m.	0.97	10:00 a. m.	10:18 a. m.	0.01	0.22	0.58	0.64	0.69	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
		8:20 p. m.	11:50 p. m.	0.89	9:17 p. m.	10:00 p. m.	0.05	0.14	0.17	0.20	0.23	0.29	0.34	0.53	0.61	0.65	.....	.....	.....	.....	.....
Atlanta, Ga.	30	.....	.....	1.06	.....	.....	0.08	.....	.....	0.41	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Atlantic City, N. J.	14	.....	.....	2.26	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.70	.....	.....	.....
Augusta, Ga.	27	.....	.....	0.48	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.19	.....	.....	.....
Baker City, Oreg.	26–27	.....	.....	0.07	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Baltimore, Md	20	.....	.....	0.51	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.29	.....	.....	.....
Bentonville, Ark.	12	.....	.....	1.46	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.65	.....	.....	.....
Binghamton, N. Y.	30	.....	.....	0.62	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.42	.....	.....	.....
Birmingham, Ala.	22	.....	.....	.....	.....	.....	.....	.....	.....	0.52	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Do	23	.....	.....	.....	.....	.....	.....	.....	.....	0.61	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Do	30	4:15 p. m.	D. N.	1.90	4:29 p. m.	5:26 p. m.	0.01	0.12	0.15	0.20	0.35	0.54	0.69	0.78	0.79	0.84	1.09	1.31	.....	.....	.....
Bismarck, N. Dak.	24	.....	.....	0.47	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Block Island, R. I.	14	.....	.....	2.60	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.75	.....	.....	.....
Boise, Idaho	27	.....	.....	0.15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.05	.....	.....	.....
Boston, Mass.	14	.....	.....	0.90	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.35	.....	.....	.....
Buffalo, N. Y.	13	.....	.....	1.14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.55	.....	.....	.....
Burlington, Vt.	13–14	.....	.....	0.68	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Cairo, Ill.	19	.....	.....	1.87	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.65	.....	.....	.....
Canton, N. Y.	25	.....	.....	0.23	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.14	.....	.....	.....
Charles City, Iowa	18	.....	.....	1.02	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.29	.....	.....	.....
Charleston, S. C.	25	.....	.....	1.48	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.54	.....	.....	.....
Charlotte, N. C.	30	.....	.....	2.00	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.68	.....	.....	.....
Chattanooga, Tenn.	30	5:55 a. m.	9:16 a. m.	1.30	7:00 a. m.	8:20 a. m.	0.07	0.12	0.13	0.18	0.24	0.33	0.46	0.46	0.46	0.47	0.61	0.76	1.09	.....	.....
Cheyenne, Wyo.	4–5	.....	.....	0.45	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Chicago, Ill.	29	.....	.....	2.75	.....	.....	.....	.....	0.37	.....	.....	.....	.....	.....	.....	.....	.....	0.65	.....	.....	.....
Cincinnati, Ohio.	6	.....	.....	0.75	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.35	.....	.....	.....
Cleveland, Ohio	29	.....	.....	1.27	.....	.....	.....	.....	0.49	.....	.....	.....	.....	.....	.....	.....	.....	0.55	.....	.....	.....
Columbia, Mo.	6	.....	.....	0.60	.....	.....	.....	.....	.....	0.54	.....	.....	.....	.....	.....	.....	.....	0.60	.....	.....	.....
Columbia, S. C.	30	.....	.....	0.31	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.31	.....	.....	.....
Columbus, Ohio.	30	.....	.....	0.78	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.40	.....	.....	.....
Concord, N. H.	21	.....	.....	0.24	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.13	.....	.....	.....
Concordia, Kans.	17	.....	.....	0.55	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.45	.....	.....	.....
Corpus Christi, Tex.	8	.....	.....	0.54	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.21	.....	.....	.....
Davenport, Iowa	18	2:20 p. m.	7:40 p. m.	1.91	4:12 p. m.	5:12 p. m.	0.20	0.11	0.16	0.19	0.28	0.46	0.68	0.69	0.74	0.80	0.98	1.38	.....	.....	.....
Del Rio, Tex.	26	.....	.....	0.74	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.60	.....	.....	.....
Denver, Colo.	4–5	.....	.....	1.26	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*	.....	.....	.....
Des Moines, Iowa	18	.....	.....	0.71	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.45	.....	.....	.....
Detroit, Mich.	18	.....	.....	0.54	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.51	.....	.....	.....
Devils Lake, N. Dak.	29–30	.....	.....	0.17	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Dodge City, Kans.	21	.....	.....	0.02	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.02	.....	.....	.....
Dubuque, Iowa	17–18	8:45 p. m.	D. N.	1.38	9:37 p. m.	10:14 p. m.	0.02	0.23	0.31	0.34	0.38	0.43	0.52	0.58	0.60	.....	.....	.....	.....	.....	.....
Duluth, Minn.	29–30	.....	.....	0.63†	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*	.....	.....	.....
Durango, Colo.	21–22	.....	.....	0.36	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*	.....	.....	.....
Eastport, Me.	22	.....	.....	0.63	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.21	.....	.....	.....
Elkins, W. Va.	13	.....	.....	1.18	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.31	.....	.....	.....

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, etc.*—Continued.

Stations.	Date.	Total duration. From—	Total duration. To—	Total amount of precipitation.	Excessive rate. Began—	Excessive rate. Ended—	Amount before excessive began.	Depths of precipitation (in inches) during periods of time indicated. 5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
El Paso, Tex	‡																				
Erie, Pa	29			2.31														0.34			
Escanaba, Mich	6			0.97														0.33			
Eureka, Cal	27			0.24														0.18			
Evansville, Ind	29–30	10:45 p. m.	3:00 a. m.	1.07	11:00 p. m.	11:30 p. m.	0.01	0.13	0.39	0.50	0.67	0.79	0.89								
Flagstaff, Ariz	5			0.14														*			
Fort Smith, Ark	20–21	8:46 p. m.	D. N.	1.54	10:03 p. m.	10:35 p. m.	0.13	0.11	0.35	0.45	0.49	0.61	0.74	0.78							
Fort Worth, Tex	5	8:10 p. m.	9:45 p. m.	0.93	9:13 p. m.	9:28 p. m.	0.21	0.28	0.62	0.72											
Fresno, Cal	19			T.														T.			
Galveston, Tex	7–8	4:45 p. m.	D. N.	2.55	6:39 p. m.	7:15 p. m.	0.01	0.07	0.21	0.29	0.52	0.75	0.91	0.99	1.00						
Grand Haven, Mich	6			0.78														0.54			
Grand Junction, Colo	18–19			0.73														*			
Grand Rapids, Mich	29			2.53†														0.50			
Green Bay, Wis	29–30			1.50																	
Greenville, Me	14–15			0.97																	
Hannibal, Mo	18	5:15 p. m.	9:40 p. m.	2.17	6:30 p. m.	7:48 p. m.	0.05	0.14	0.26	0.40	0.56	0.79	0.98	1.21	1.29	1.33	1.44	1.69	2.02		
Harrisburg, Pa	29			0.41														0.30			
Hartford, Conn	14			3.57														0.60			
Hatteras, N. C	27			0.79			0.10	0.10	0.21	0.28	0.39	0.48									
Do	27–28	6:45 p. m.	2:20 a. m.	2.19	11:25 p. m.	12:40 a. m.	0.70	0.11	0.22	0.29	0.37	0.47	0.53	0.63	0.73	0.82	0.89	0.99	1.27		
Havre, Mont	12–13			0.42														*			
Helena, Mont	26			0.42														*			
Houghton, Mich	6–7			0.78														*			
Huron, S. Dak	27			0.20														0.18			
Independence, Cal	17			0.12														0.12			
Indianapolis, Ind	6			1.89														0.56			
Iola, Kans	5			1.58			0.03	0.33	0.59	0.68											
Do	12			0.98			0.01	0.21	0.28	0.31	0.36	0.45	0.54	0.58							
Jacksonville, Fla	9			0.55														0.47			
Jupiter, Fla	11	6:38 a. m.	3:30 p. m.	2.50	7:15 a. m.	9:10 a. m.	0.03	0.14	0.25	0.29	0.32	0.36	0.47	0.51	0.52	0.55	0.64	0.81	0.93	1.46	1.62
Kalispell, Mont	28			0.38														*			
Kansas City, Mo	16	10:30 p. m.	D. N.	0.63	10:39 p. m.	10:52 p. m.	0.01	0.16	0.45	0.62											
Keokuk, Iowa	18	5:40 p. m.	9:10 p. m.	0.63	5:54 p. m.	6:11 p. m.	T.	0.15	0.42	0.51	0.55										
Key West, Fla	1	9:40 a. m.	11:40 a. m.	0.86	11:10 a. m.	11:38 a. m.	0.17	0.11	0.37	0.49	0.53	0.65	0.69								
Knoxville, Tenn	7			1.29							0.57										
Do	30			2.05						0.50											
La Crosse, Wis	28–29			1.40														*			
Lander, Wyo	4			0.78														*			
La Salle, Ill	18	5:10 p. m.	10:00 p. m.	1.25	6:47 p. m.	7:00 p. m.	0.09	0.42	0.67	0.73											
Lewiston, Idaho	26			0.20														0.07			
Lexington, Ky	29–30			2.47			0.39	0.09	0.17	0.46	0.63	0.68									
Lincoln, Nebr	6			0.27														0.16			
Little Rock, Ark	29	8:25 p. m.	9:30 p. m.	0.62	8:51 p. m.	9:00 p. m.	0.03	0.34	0.55												
Do	12	11:10 a. m.	5:20 p. m.	1.77	1:43 p. m.	2:28 p. m.	0.23	0.08	0.25	0.36	0.48	0.62	0.74	0.84	0.91	0.97					
Los Angeles, Cal	16			T.														T.			
Louisville, Ky	30			1.10														0.62†			
Lynchburg, Va	30			0.75														0.36			
Macon, Ga	23			0.55			0.08	0.21	0.46												
Do	30			1.14			0.09	0.21	0.33	0.53	0.64	0.69									
Madison, Wis	18			2.01†														0.37			
Marquette, Mich	29–30			1.06														*			
Memphis, Tenn	6			2.72			0.11	0.32	0.48	0.57	0.61	0.66	0.82								
Do	6			2.72			1.76	9.15	0.30	0.42	0.46	0.51	0.66	0.76	0.89	0.92					
Do	12–13			2.01			0.12	0.06	0.15	0.26	0.31	0.41	0.47	0.50	0.60	0.67	0.71				
Meridian, Miss	7	1:32 a. m.	6:00 a. m.	1.80	1:36 a. m.	2:21 a. m.	0.01	0.18	0.45	0.59	0.67	0.82	0.92	1.00	1.07	1.14					
Do	12–13	10:30 p. m.	D. N.	1.44	10:35 p. m.	10:55 p. m.	0.01	0.30	0.48	0.58	0.66										
Do	25	D. N.	5:40 p. m.	3.30	7:30 a. m.	7:40 a. m.	1.49	0.26	0.53												
Milwaukee, Wis	6			0.50														0.43			
Minneapolis, Minn	6–7			0.60														*			
Mobile, Ala	7–8	9:30 p. m.	5:15 p. m.	3.23	§ 2:40 a. m.	4:40 a. m.	0.98	0.07	0.12	0.18	0.25	0.32	0.37	0.43	0.47	0.52	0.59	0.67	0.89	1.11	1.39
					‖ 4:40 a. m.	4:59 a. m.		0.06	0.11	0.15	0.23										
Do	24	4:15 p. m.	8:40 p. m.	0.90	4:37 p. m.	5:07 p. m.	0.01	0.19	0.29	0.32	0.33	0.38	0.50								
Do	26–27	D. N.	D. N.	1.85	3:15 a. m.	3:55 a. m.	0.90	0.09	0.13	0.16	0.26	0.44	0.55	0.70	0.90						
Do	30	9:30 p. m.	11:55 p. m.	0.84	9:49 p. m.	10:30 p. m.	0.04	0.17	0.29	0.32	0.33	0.46	0.52	0.54	0.65	0.69					
Modena, Utah	18–19			0.11														*			
Montgomery, Ala	13			0.90			0.01				0.49										
Do	23			1.56	6:51 a. m.	7:38 a. m.	0.09	0.24	0.57	0.77	0.89	1.08	1.23	1.33	1.35	1.41	1.44				
Do	30			1.57	8:29 p. m.	9:02 p. m.	0.03	0.16	0.40	0.53	0.76	1.00	1.16	1.23							
Moorhead, Minn	30			0.34														*			
Mount Tamalpais, Cal	17			T.														T.			
Mount Weather, Va	13–14			3.02														0.66			
Nantucket, Mass	23			1.10														0.66			
Nashville, Tenn	12			0.77			0.06					0.46									
New Haven, Conn	14			2.67														0.70			
New Orleans, La	7–8	8:05 p. m.	1:45 p. m.	4.34	§12:12 a. m.	12:56 a. m.	0.63	0.15	0.18	0.20	0.29	0.48	0.51	0.61	0.77	0.83					
					‖ 5:05 a. m.	5:31 a. m.	2.84	0.11	0.19	0.33	0.53	0.61	0.63								
Do	12–13	9:20 p. m.	D. N.	1.35	11:25 p. m.	12:10 a. m.	0.09	0.15	0.55	0.69	0.76	0.80	0.84	0.88	0.93	0.98					
Do	23	6:14 a. m.	8:45 a. m.	1.26	6:27 a. m.	7:29 a. m.	0.01	0.06	0.14	0.20	0.26	0.31	0.44	0.63	0.80	0.86	0.91	1.12	1.18		
Do	30	8:30 p. m.	9:15 p. m.	0.65	8:47 p. m.	9:03 p. m.	T.	0.20	0.48	0.62	0.64										
New York, N. Y	14			2.64														0.43			
Norfolk, Va	14–15	5:15 p. m.	D. N.	0.81	7:09 p. m.	7:29 p. m.	0.08	0.10	0.20	0.33	0.40										
Northfield, Vt	14			0.79														0.13			
North Head, Wash	26			0.53														0.10			
North Platte, Nebr	5–6			0.26														*			
Oklahoma, Okla	25	8:10 p. m.	9:05 p. m.	1.13	8:27 p. m.	8:42 p. m.	0.01	0.45	0.81	1.09											
Omaha, Nebr	24			0.24														0.17			
Oswego, N. Y	13–14			1.27														*			
Palestine, Tex	12	9:54 a. m.	11:40 a. m.	1.23	10:19 a. m.	11:15 a. m.	0.04	0.24	0.39	0.47	0.54	0.62	0.67	0.78	0.89	0.98	1.04	1.14			
Parkersburg, W. Va	30	3:37 p. m.	7:48 p. m.	0.67	7:10 p. m.	7:36 p. m.	0.09	0.05	0.07	0.17	0.48	0.55	0.57								
Pensacola, Fla	24	5:40 p. m.	11:00 p. m.	1.56	8:24 p. m.	9:44 p. m.	0.02	0.07	0.14	0.27	0.45	0.50	0.54	0.59	0.64	0.66	0.68	0.98	1.37		
Peoria, Ill	5–6	9:05 p. m.	D. N.	1.21	10:06 p. m.	10:40 p. m.	0.26	0.08	0.17	0.53	0.70	0.75	0.80	0.85							
Philadelphia, Pa	14			2.11														0.43			
Phoenix, Ariz	5			0.07														0.06			
Pierre, S. Dak	15–16			0.26														*			
Pittsburg, Pa	6			0.91														0.45			
Pocatello, Idaho	20–21			0.32														*			
Point Reyes Light, Cal	17			T.														T.			
Port Huron, Mich	29–30			2.06														0.48			
Portland, Me	15			0.76														0.15			
Portland, Oreg	3			0.23														0.16			
Providence, R. I	28			0.87														0.43			
Pueblo, Colo	29			0.07†														0.05			
Raleigh, N. C	5	1:50 p. m.	5:20 p. m.	1.05	1:53 p. m.	2:13 p. m.	0.01	0.07	0.23	0.55	0.67										
Do	30–1	8:30 p. m.	6:20 a. m.	2.25	8:35 p. m.	9:02 p. m.	0.01	0.18	0.56	0.80	0.94	0.99	1.04								

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, etc.*—Continued.

Stations.	Date.	Total duration. From—	Total duration. To—	Total amount of precipitation.	Excessive rate. Began—	Excessive rate. Ended—	Amount before excessive began.	Depths of precipitation (in inches) during periods of time indicated. 5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Rapid City, S. Dak	28-29			0.12														*			
Red Bluff, Cal	18			0.03														*			
Reno, Nev	19			0.18														0.16			
Richmond, Va	30			0.74														0.60			
Rochester, N. Y	13			0.79														0.34			
Roseburg, Oreg	27			0.12														0.05			
Roswell, N. Mex	†																				
Sacramento, Cal	27			T.														T			
St. Louis, Mo	6	3:00 p. m.	4:40 p. m.	0.73	3:24 p. m.	3:53 p. m.	0.01	0.25	0.33	0.38	0.53	0.57	0.63								
Do	18-19	7:45 p. m.	2:30 a. m.	0.91	10:23 p. m.	10:43 p. m.	0.20	0.05	0.11	0.26	0.40										
St. Paul, Minn	24			0.39														0.23			
Salt Lake City, Utah	29			0.41														*			
San Antonio, Tex	27			0.49														0.41			
San Diego, Cal	18			0.02														0.02			
Sand Key, Fla	11			0.32														0.32			
Sandusky, Ohio	29			0.79														0.35			
San Francisco, Cal	17			T.														T.			
San Jose, Cal	†																				
San Luis Obispo, Cal	18			0.03														0.02			
Santa Fe, N. Mex	22-23			0.19														*			
Sault Sainte Marie, Mich	12-13			1.04														*			
Savannah, Ga	25			0.54														0.30			
Scranton, Pa	14			1.06														0.30			
Seattle, Wash	16			0.10														0.07			
Sheridan, Wyo	20-21			0.27														*			
Shreveport, La	30	7:45 a. m.	8:50 a. m.	0.60	7:56 a. m.	8:08 a. m.	0.02	0.15	0.37	0.48											
Sioux City, Iowa	28-29			0.61														*			
Southeast Farallon, Cal	†																				
Spokane, Wash	10			0.23														0.06			
Springfield, Ill	6	3:19 p. m.	4:48 p. m.	0.71	3:29 p. m.	3:51 p. m.	0.02	0.06	0.35	0.45	0.59	0.64									
Springfield, Mo	22			1.26														0.43			
Syracuse, N. Y	13			0.53														0.32			
Tacoma, Wash	9			0.18														0.17			
Tampa, Fla	9			0.48														0.22			
Tatoosh Island, Wash	24			0.19														0.13			
Taylor, Tex	26-27	9:25	D. N.	0.94	10:33 p. m.	10:58 p. m.	0.13	0.29	0.40	0.52	0.58	0.67									
Thomasville, Ga	23	1:45 p. m.	2:30 p. m.	0.81	2:03 p. m.	2:14 p. m.	0.03	0.35	0.68	0.70											
Toledo, Ohio	29			1.51														0.50			
Tonopah, Nev	18-19			0.06														0.04			
Topeka, Kans	12			0.52														0.42			
Valentine, Nebr	20-21			0.62														*			
Vicksburg, Miss	12	5:45 p. m.	D. N.	2.24	7:00 p. m.	7:40 p. m.	0.03	0.74	1.10	1.25	1.36	1.46	1.57	1.66	1.73						
Do	25	12:40 a. m.	D. N.	1.22	2:56 a. m.	3:32 a. m.	0.33	0.09	0.17	0.36	0.63	0.72	0.77	0.83	0.89						
Walla Walla, Wash	27			0.38														0.11			
Washington, D. C	14			1.42														0.35			
Wichita, Kans	26	6:00 p. m.	7:10 p. m.	0.78	6:14 p. m.	6:28 p. m.	0.02	0.26	0.57	0.65											
Williston, N. Dak	3-4			0.45														*			
Wilmington, N. C	13	7:28 p. m.	9:20 p. m.	0.65	7:44 p. m.	7:56 p. m.	0.05	0.16	0.37	0.41											
Winnemucca, Nev	19			0.19														*			
Wytheville, Va	30			1.56														0.63			
Yankton, S. Dak	20-21			0.65														*			
Yellowstone Park, Wyo	10			0.36														*			

* Self register not working. † Estimated. ‡ No precipitation reported during month. § May 1.

TABLE III.—*Data furnished by the Canadian Meteorological Service, April, 1909.*

Stations.	Pressure.			Temperature.				Precipitation.			Stations.	Pressure.			Temperature.				Precipitation.		
	Actual, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean.	Departure from normal.	Mean maximum.	Mean minimum.	Total.	Departure from normal.	Total snowfall.		Actual, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean.	Departure from normal.	Mean maximum.	Mean minimum.	Total.	Departure from normal.	Total snowfall.
	Ins.	*Ins.*	*Ins.*	°	°	°	°	*Ins.*	*Ins.*	*Ins.*		*Ins.*	*Ins.*	*Ins.*	°	°	°	°	*Ins.*	*Ins.*	*Ins.*
St. Johns, N. F.	29.72	29.86	—.03	34.9	+ 0.4	40.6	29.1	3.26	—0.90	5.0	Parry Sound, Ont.	29.28	29.98	—.04	35.4	— 2.2	44.1	26.7	3.97	+2.06	9.5
Sydney, C. B. I.	29.95	29.99	+.10	37.4	+ 2.4	44.8	30.1	2.34	—1.51	8.0	Port Arthur, Ont.	29.24	29.95	—.08	30.9	— 2.6	40.2	21.7	0.64	—1.08	3.0
Halifax, N. S.	29.91	30.02	+.06	38.6	+ 0.8	46.2	31.1	3.99	—0.19	19.5	Winnipeg, Man.	29.15	30.01	—.01	30.3	— 5.6	39.3	21.4	1.58	+0.53	14.5
Grand Manan, N. B.	29.96	30.01	+.07	38.8	— 0.4	45.3	32.2	5.86	+2.90	13.2	Minnedosa, Man.	28.11	29.98	—.03	27.7	— 8.3	36.9	18.4	1.60	+0.54	15.4
Yarmouth, N. S.	29.96	30.03	+.07	38.9	0.0	45.3	32.6	3.79	+0.40	10.1	Qu' Appelle, Assin.	27.66	29.97	—.02	27.2	—10.2	36.4	17.9	1.78	+0.73	0.0
Charlottetown, P. E. I.	29.94	29.98	+.08	36.1	+ 0.9	42.8	29.3	4.20	+1.55	14.5	Medicine Hat, Alberta.	27.68	30.00	+.08	36.8	— 7.7	48.6	25.0	0.30	—0.44	3.0
Chatham, N. B.	29.97	29.99	+.09	35.2	— 0.3	43.9	26.5	4.36	+1.73	22.0	Swift Current, Sask.	27.38	30.00	+.04	30.6	—10.7	40.5	20.6	0.45	—0.48	0.0
Father Point, Que.	29.96	29.98	+.05	33.2	0.0	40.5	25.9	1.60	+0.02	3.8	Calgary, Alberta.	26.40	30.01	+.11	32.6	— 7.0	43.6	21.6	1.14	+0.50	11.4
Quebec, Que.	29.67	30.01	+.02	34.8	— 0.3	42.4	27.3	3.01	+0.92	3.3	Banff, Alberta.	25.33	30.04	+.14	29.0	— 6.3	39.1	18.9	0.92	—0.16	9.1
Montreal, Que.	29.79	30.00	.00	38.6	— 1.1	45.3	31.9	3.03	+0.79	9.0	Edmonton, Alberta.	27.69	30.04	+.15	31.2	— 8.7	42.4	19.9	0.91	+0.03	9.1
Rockliffe, Ont.	29.36	29.99	—.03	32.6	— 5.3	41.7	23.5	1.71	+0.15	0.7	Prince Albert, Sask.	28.39	29.99	+.01	23.3	—12.8	33.6	13.1	0.93	+0.10	0.0
Ottawa, Ont.	29.74	30.07	+.05	37.2	— 2.8	45.6	28.8	3.86	+2.36	11.0	Battleford, Sask.	28.24	30.03	+.06	26.6	—10.6	35.7	17.4	0.04	—0.43	0.0
Kingston, Ont.	29.70	30.02	.00	39.7	— 0.3	47.1	32.1	2.93	+1.14	1.6	Kamloops, B. C.	28.72	30.00	+.07	47.1	— 1.8	58.3	35.9	0.30	—0.09	0.0
Toronto, Ont.	29.62	30.01	—.01	40.9	+ 0.1	48.8	33.0	5.40	+3.03	5.1	Victoria, B. C.	30.08	30.18	+.17	47.2	— 0.4	55.2	39.3	0.61	—1.76	0.0
White River, Ont.	28.59	29.94	—.10	27.6	— 5.4	39.2	15.9	3.19	+1.94	31.0	Barkerville, B. C.	25.64	30.02	+.16	29.4	— 3.7	38.9	20.0	3.62	+1.80	0.0
Port Stanley, Ont.	29.35	30.01	—.01	39.4	— 1.6	47.4	31.4	4.64	+2.17	9.7	Hamilton, Bermuda.	30.07	30.24	.....	64.8	+ 0.9	69.7	59.8	2.06	—2.12	0.0
Southampton, Ont.	29.27	29.99	—.04	38.0	— 0.7	46.7	29.2	5.76	+3.96	9.4	Dawson, Yukon.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

TABLE IV.—*Heights of rivers referred to zeros of gages, April, 1909.*

Stations.	Distance to mouth of river.	Flood stage on gage.	Highest water.		Lowest water.		Mean stage.	Monthly range.	Stations.	Distance to mouth of river.	Flood stage on gage.	Highest water.		Lowest water.		Mean stage.	Monthly range.
			Height.	Date.	Height.	Date.						Height.	Date.	Height.	Date.		
Republican River.	*Miles.*	*Feet.*	*Feet.*		*Feet.*		*Feet.*	*Feet.*	*South Fork Holston River.*	*Miles.*	*Feet.*	*Feet.*		*Feet.*		*Feet.*	*Feet.*
Clay Center, Kans.	42	18	6.8	1-3	6.2	24-30	6.4	0.6	Bluff City, Tenn.	35	12	2.8	1	1.5	30	1.9	1.3
Smoky Hill-Kansas River.									*Holston River.*								
Abilene, Kans.	254	22	0.9	21	0.4	5	0.7	0.5	Rogersville, Tenn.	103	14	5.0	30	2.8	19, 20	3.2	2.2
Manhattan, Kans.	160	18	3.5	13, 14	3.0	11	3.3	0.5	*French Broad River.*								
Topeka, Kans.	87	21	6.8	1	6.2	10-12, 26-30	6.4	0.6	Asheville, N. C.	144	4	2.0	14	0.3	30	0.8	1.7
Missouri River.									Dandridge, Tenn.	46	12	3.9	1, 15	1.9	28, 29	2.6	2.0
Townsend, Mont.	2,504	11	5.6	23, 28	4.9	1, 4-7, 9-13	5.1	0.7	*Tennessee River.*								
Fort Benton, Mont.	2,285	12	2.6	30	2.1	1-11	2.3	0.5	Knoxville, Tenn.	635	12	5.7	1	2.5	14	3.2	3.2
Wolfpoint, Mont. (5)	1,951	17	3.9	7	0.3	28	2.0	3.6	Loudon, Tenn.	590	25	6.8	1	1.9	20-22, 30	2.8	4.9
Bismarck, N. Dak.	1,309	14	9.5	4	1.9	23	5.0	7.6	Kingston, Tenn.	556	25	8.7	1	4.3	20	5.4	4.4
Pierre, S. Dak.	1,114	14	5.2	12	1.7	25, 26	3.4	3.5	Chattanooga, Tenn.	452	33	16.5	1	6.0	21	8.5	10.5
Sioux City, Iowa.	784	17	9.2	15	6.4	30	7.7	2.8	Bridgeport, Ala.	402	24	12.4	1	4.1	23	6.4	8.3
Blair, Nebr.	705	15	9.4	16	6.6	30	7.9	2.8	Guntersville, Ala.	349	31	20.7	1	7.9	22	11.8	12.8
Omaha, Nebr.	669	18	12.4	16	9.4	30	10.8	3.0	Florence, Ala.	255	16	11.5	1, 2	4.7	22	7.4	6.8
Plattsmouth, Nebr.	641	17	6.3	16, 17	4.1	29	5.3	2.2	Riverton, Ala.	225	32	25.1	2	14.4	23	18.6	10.7
St. Joseph, Mo.	481	10	6.2	18	3.9	29	5.0	2.3	Johnsonville, Tenn.	98	25	17.5	3	8.5	25	12.9	9.0
Kansas City, Mo.	388	21	12.9	2	10.2	29, 30	11.5	2.7	*Ohio River.*								
Glasgow, Mo.	231	21	15.0	22	12.3	11, 30	13.6	2.7	Pittsburg, Pa.	966	22	13.8	23	4.7	13	7.8	9.1
Boonville, Mo.	199	20	14.2	23	11.4	30	13.1	2.8	Coraopolis, Pa.	956	25	14.4	23	6.7	13	9.2	7.7
Hermann, Mo.	103	24	15.7	22	9.9	10	12.0	5.8	Beaver Dam, Pa.	937	27	20.6	23	9.7	13	13.3	10.9
Minnesota River.									Wheeling, W. Va.	875	36	20.2	24	9.2	14	12.9	11.0
Mankato, Minn.	127	18	16.7	1	7.7	29	11.5	9.0	Parkersburg, W. Va.	785	36	21.9	25	10.0	6	13.9	11.9
St. Croix River.									Point Pleasant, W. Va.	703	39	27.0	25	11.2	6	17.5	15.8
Stillwater, Minn.	23	11	11.7	7, 8	8.1	30	9.9	3.6	Huntington, W. Va.	660	50	31.4	26	15.6	15	21.9	15.8
Illinois River.									Catlettsburg, Ky.	651	50	32.4	26	15.4	15	22.4	17.0
La Salle, Ill.	197	18	22.4	23	16.1	5, 6	19.1	6.3	Portsmouth, Ohio.	612	50	32.6	26	15.4	7	22.7	17.2
Peoria, Ill.	135	14	17.4	26, 27	12.9	5-7, 12	14.7	4.5	Maysville, Ky.	559	50	32.1	26, 27	16.5	8, 16	23.1	15.6
Conemaugh River.									Cincinnati, Ohio.	499	50	34.2	27	18.9	17	25.4	15.3
Johnstown, Pa.	64	7	8.0	14	2.5	1-4	4.0	5.5	Madison, Ind.	413	46	29.3	28	16.9	18	22.4	12.4
Allegheny River.									Louisville, Ky.	367	28	12.2	28	8.1	18	10.0	4.1
Warren, Pa.	177	14	11.9	30	2.0	26, 27	3.6	9.9	Evansville, Ind.	184	35	28.7	24, 25	17.1	1	22.0	11.6
Parker, Pa.	73	20	18.6	30	2.9	28	4.6	15.7	Mount Vernon, Ind.	148	35	28.5	24, 25	16.0	1	21.5	12.5
Freeport, Pa.	29	20	25.2	30	6.9	6, 13, 28	8.8	18.3	Paducah, Ky.	47	40	30.3	28, 29	21.4	10	24.9	8.9
Springdale, Pa.	17	27	22.0	30	12.0	13, 28	13.8	10.0	Cairo, Ill.	1	45	40.8	27, 28	30.2	10, 11	34.2	10.6
Youghiogheny River.									*Neosho River.*								
Confluence, Pa.	59	10	6.0	22	1.4	11	2.8	4.6	Iola, Kans.	262	10	4.5	6	— 1.0	30	—0.1	5.5
West Newton, Pa.	15	23	9.9	22	2.0	11	4.0	7.9	Oswego, Kans.	184	20	8.7	8	0.7	5, 6	2.0	8.0
Monongahela River.									Fort Gibson, Okla.	3	22	13.8	25	9.8	10	11.0	4.0
Fairmont, W. Va.	119	25	21.1	22	15.0	13	16.7	6.1	*Black River.*								
Greensboro, Pa.	81	18	16.4	22	7.9	13	10.3	8.5	Blackrock, Ark.	67	12	19.2	29, 30	6.1	12	13.5	13.1
Lock No. 4, Pa.	40	28	21.7	22	8.5	13	12.3	13.2	*White River.*								
Muskingum River.									Calicorock, Ark.	272	18	18.8	22	1.4	12	6.0	17.4
Zanesville, Ohio.	70	25	18.7	8	9.4	20, 21	11.4	9.3	Batesville, Ark.	217	18	19.6	23	3.3	12	8.1	16.3
Little Kanawha River.									Newport, Ark.	185	26	24.1	26	5.9	12	15.0	18.2
Creston, W. Va.	38	20	11.6	23	2.8	13, 14	4.9	8.8	Clarendon, Ark.	75	30	27.3	1	23.5	15, 16	24.9	3.8
New-Great Kanawha River.									*Arkansas River.*								
Hinton, W. Va.	153	14	8.4	15	2.5	13	3.6	5.9	Wichita, Kans.	832	10	— 1.2	1, 2	— 2.1	19, 23-27	—1.8	0.9
Charleston, W. Va.	58	30	12.9	16	5.1	13	7.5	7.8	Tulsa, Okla.	551	16	2.9	1	2.0	19, 20	2.4	0.8
Scioto River.									Webbers Falls, Okla.	465	23	8.1	11	5.9	17	6.8	2.2
Columbus, Ohio.	110	17	8.2	7	1.5	19, 20	2.9	6.7	Fort Smith, Ark.	403	22	8.9	25	4.6	10	6.7	4.3
Licking River.									Dardanelle, Ark.	256	21	8.5	27	4.8	12	6.5	3.7
Falmouth, Ky.	30	25	12.0	23	2.0	5	4.5	10.0	Little Rock, Ark.	176	23	9.5	15	4.5	12	6.7	5.0
Kentucky River.									Pine Bluff, Ark.	121	25	14.4	1, 16	9.2	13	11.8	5.2
Beattyville, Ky.	254	30	7.5	23	0.8	19	2.9	6.7	*Yazoo River.*								
Frankfort, Ky.	65	31	12.7	30	6.5	19	8.6	6.2	Greenwood, Miss.	175	38	29.7	1	21.5	22, 23	24.5	8.2
Wabash River.									Yazoo City, Miss.	80	25	25.9	3-7	22.2	25, 30	24.3	3.7
Terre Haute, Ind.	171	16	15.1	12	3.3	6	9.1	11.8	*Ouachita River.*								
Mount Carmel, Ill.	75	15	14.4	13	5.2	7	10.7	9.2	Camden, Ark.	304	39	18.3	16	6.4	12	9.6	11.9
Cumberland River.									Monroe, La.	122	40	30.0	1	21.9	25	25.4	8.1
Burnside, Ky.	518	50	16.5	23	3.2	20	7.5	13.3	*Red River.*								
Celina, Tenn.	383	45	19.0	25	5.7	20	11.4	13.3	Arthur City, Tex.	688	27	8.7	30	5.8	20	6.8	2.9
Carthage, Tenn.	308	40	18.6	1	4.9	20	10.1	13.7	Fulton, Ark.	515	28	13.5	16	8.7	10-15	10.5	4.8
Nashville, Tenn.	193	40	26.5	1	11.2	20	16.4	15.3	Shreveport, La.	327	29	4.0	1, 2, 19	1.0	16	2.6	3.0
Clarksville, Tenn.	126	43	29.0	1	11.9	20	18.5	17.1	Alexandria, La.	118	36	11.6	1	7.6	19, 28	9.6	4.0
Clinch River.									*Mississippi River.*								
Speers Ferry, Va.	156	20	4.5	25	0.5	20	1.9	4.0	Fort Ripley, Minn. (5)	2,082	10	7.2	7	4.8	14	5.4	2.4
Clinton, Tenn.	52	25	11.4	1	5.2	20	7.9	6.2	St. Paul, Minn.	1,964	14	13.0	4, 5	7.4	29, 30	10.1	5.6

TABLE IV.—*Heights of rivers referred to zeros of gages*—Continued.

Stations.	Distance to mouth of river.	Flood stage on gage.	Highest water.		Lowest water.		Mean stage.	Monthly range.
			Height.	Date.	Height.	Date.		
Mississippi River.—Cont'd.	*Miles.*	*Feet.*	*Feet.*		*Feet.*		*Feet.*	*Feet.*
Red Wing, Minn	1,914	14	8.4	10–12	5.2	1	7.1	3.2
Reeds Landing, Minn	1,884	12	7.7	12	4.8	1	6.6	2.9
La Crosse, Wis	1,819	12	9.4	12	6.7	3	8.2	2.7
Prairie du Chien, Wis. (1)	1,759	18	11.3	19	7.2	2	9.4	4.1
Dubuque, Iowa	1,690	18	13.2	20	6.5	1	10.4	6.3
Clinton, Iowa	1,629	16	12.4	22	6.2	1	9.5	6.2
Leclaire, Iowa	1,609	10	8.0	22	3.6	1	5.8	4.4
Davenport, Iowa	1,593	15	11.6	23	6.0	1,2	8.7	5.6
Muscatine, Iowa	1,562	16	13.1	23,24	7.3	1–3	10.1	5.8
Galland, Iowa	1,472	8	7.1	26,27	4.0	1	5.4	3.1
Keokuk, Iowa	1,463	15	13.5	26,27	7.9	1	10.2	5.6
Warsaw, Ill	1,458	18	16.4	25	11.1	1	13.3	5.3
Hannibal, Mo	1,402	13	14.8	26–29	9.2	1	11.6	5.6
Grafton, Ill	1,306	23	18.0	24–26	11.3	1	14.0	6.7
St. Louis, Mo	1,264	30	25.2	23	15.4	11,12	19.1	9.8
Chester, Ill	1,189	30	23.6	24	13.8	6	17.4	9.8
Cape Girardeau, Mo	1,128	28	28.3	24,25	18.1	6–8,12	21.9	10.2
New Madrid, Mo	1,003	34	33.0	28,29	24.9	10–12	27.9	8.1
Memphis, Tenn	843	33	31.8	30	23.5	12	26.6	8.3
Helena, Ark	767	42	42.7	1	31.2	11	34.9	11.5
Arkansas City, Ark	635	42	49.6	1	37.9	17	41.4	11.7
Greenville, Miss	595	42	44.4	1	32.2	18-20,22,23	35.8	12.2
Vicksburg, Miss	474	45	48.1	2,3	38.6	25,26	42.6	9.5
Natchez, Miss	373	46	47.9	2–4	40.0	26,27	44.0	7.9
Baton Rouge, La	240	35	36.2	7,8	29.8	29,30	33.5	6.4
Donaldsonville, La	188	28	28.7	7	23.4	27	26.4	5.3
New Orleans, La	108	18	17.9	3	14.5	27,28	16.5	3.4
Atchafalaya River.								
Simmesport, La	127	41	39.8	8,9	34.0	30	37.6	5.8
Melville, La	168	37	36.1	6–10	32.5	30	34.8	3.6
Morgan City, La	19	8	4.6	30	3.1	1	3.8	1.5
Hudson River.								
Troy, N. Y	154	14	11.8	16	7.2	1,30	8.7	4.6
Albany, N. Y	147	12	13.5	16	4.3	2	8.0	9.2
Delaware River.								
Hancock (E. Branch), N. Y	287	12	7.1	15	4.3	13	5.0	2.8
Hancock (W. Branch), N. Y	287	10	7.3	15	4.2	28	5.0	3.1
Port Jervis, N. Y	215	14	8.4	16	3.9	13,14	5.2	4.5
Phillipsburg, N. J	146	26	9.4	16	3.4	13,14	5.3	6.0
Trenton, N. J	92	18	6.2	16	2.6	8	3.7	3.6
North Branch Susquehanna.								
Binghamton, N. Y	183	14	9.4	15,16	3.6	29	5.3	5.8
Wilkes-Barre, Pa	60	17	17.5	13	6.4	29	9.4	11.1
West Branch Susquehanna.								
Williamsport, Pa	39	20	20.0	30	3.5	6	5.8	16.5
Susquehanna River.								
Harrisburg, Pa	69	17	11.2	16	4.3	13,14	5.8	6.9
Shenandoah River.								
Riverton, Va	58	22	9.9	15	−0.4	8–13	1.0	10.3
Potomac River.								
Cumberland, Md	290	8	6.5	14	3.2	2	4.2	3.3
Harpers Ferry, W. Va	172	18	12.0	16	0.0	13,14	4.3	12.0
James River.								
Lynchburg, Va	260	20	10.7	15	1.8	10–12	3.1	8.9
Columbia, Va	167	18	21.3	15	6.0	13	8.1	15.3
Richmond, Va	111	10	10.0	16	0.6	4,11	1.7	9.4
Dan River.								
Danville, Va	55	8	3.5	15	0.1	6–8	0.6	3.4
Roanoke River.								
Clarksville, Va	196	12	5.0	16	0.5	13	1.4	4.5
Weldon, N. C	129	30	24.5	16	11.1	13	13.1	13.4
Tar River.								
Greenville, N. C	21	22	12.3	19	5.4	13,14	7.6	6.9
Haw River.								
Moncure, N. C	171	25	10.8	15	7.6	24	8.4	3.2
Cape Fear River.								
Fayetteville, N. C	112	38	14.6	16	5.2	29,30	7.1	9.4
Pedee River.								
Cheraw, S. C	149	27	13.8	16	3.9	23	5.9	9.9
Smiths Mills, S. C	51	16	11.3	6	7.3	30	9.2	4.0
Lynch Creek.								
Effingham, S. C	35	12	7.4	16,17	4.1	29	5.8	3.3
Black River.								
Kingstree, S. C	45	12	6.7	6	2.0	30	4.7	4.7
Catawba-Wateree River.								
Mount Holly, N. C	143	15	2.8	14	2.0	3-13,17-30	2.1	0.8
Catawba, S. C	107	11	5.7	15,16	2.5	10,24	3.6	3.2
Camden, S. C	37	24	13.8	16	7.0	25	9.2	6.8

Stations.	Distance to mouth of river.	Flood stage on gage.	Highest water.		Lowest water.		Mean stage.	Monthly range.
			Height.	Date.	Height.	Date.		
Congaree River.	*Miles.*	*Feet.*	*Feet.*		*Feet.*		*Feet.*	*Feet.*
Columbia, S. C	82	15	2.9	1	1.3	25	2.0	1.6
Santee River.								
Ferguson, S. C	82	12	13.0	2,3	9.1	27	11.0	3.9
Savannah River.								
Calhoun Falls, S. C	347	15	3.3	28	1.9	21	2.5	1.4
Augusta, Ga	268	32	12.2	1	9.5	23	10.6	2.7
Oconee River.								
Dublin, Ga	79	30	7.8	1	2.0	24,25	4.1	5.8
Ocmulgee River.								
Macon, Ga	134	18	12.3	25	4.6	22	6.5	7.7
Abbeville, Ga	51	11	11.0	1	5.0	24,25	7.3	6.0
Flint River.								
Montezuma, Ga	152	20	10.2	30	4.4	24	6.9	5.8
Albany, Ga	99	20	8.8	1	3.0	24	5.3	5.8
Bainbridge, Ga	22	22	15.3	1	7.3	24	9.7	8.0
Chattahoochee River.								
Oakdale, Ga	305	21	11.1	23	7.0	21	8.3	4.1
West Point, Ga	174	20	9.6	24	3.8	22	5.1	5.8
Eufaula, Ala	90	40	15.0	28	4.8	22,23	8.1	10.2
Alaga, Ala	30	25	16.9	29	6.9	23	10.2	10.0
Coosa River.								
Rome, Ga	266	30	10.5	24	3.4	22	5.5	7.1
Gadsden, Ala	162	22	13.6	27	4.6	22	7.8	9.0
Lock No. 4, Ala	113	17	12.8	26	3.8	22	6.8	9.0
Wetumpka, Ala	12	45	32.6	28	8.6	22	15.0	24.0
Alabama River.								
Montgomery, Ala	323	35	30.0	28	6.1	23	12.3	23.9
Selma, Ala	246	35	33.9	30	8.5	23	15.2	25.4
Black Warrior River.								
Tuscaloosa, Ala	90	43	44.8	26	10.3	6	21.8	34.5
Tombigbee River.								
Columbus, Miss	316	33	15.2	28	1.0	6	7.2	14.2
Demopolis, Ala	168	35	50.0	1	15.7	23	30.6	34.3
Pascagoula River.								
Merrill, Miss	78	20	19.3	30	4.0	7	10.3	15.3
Pearl River.								
Columbia, Miss	110	18	15.6	1	7.5	12	10.6	8.1
Sabine River.								
Logansport, La	315	25	11.8	15	3.7	11,12	6.1	8.1
Neches River.								
Beaumont, Tex	18	10	2.1	22	0.7	15,22	1.2	1.4
Trinity River.								
Dallas, Tex	320	25	10.0	8	4.0	5,16,17,19	5.1	6.0
Long Lake, Tex	211	40	8.0	13	2.9	27,26	4.3	5.1
Liberty, Tex	20	25	6.1	22	4.6	9	5.2	1.5
Brazos River.								
Waco, Tex	285	24	2.5	27	1.0	4–6	1.3	1.5
Hempstead, Tex	140	40	0.7	15,25	0.0	4,16,17,30	0.3	0.7
Booth, Tex	61	39	2.3	1–7	2.1	14–30	2.2	0.2
Colorado River.								
Austin, Tex	214	18	3.5	30	0.8	25,26	1.2	2.7
Columbus, Tex	98	24	10.0	9	5.4	3-7,20-29	5.8	4.6
Red River of the North.								
Moorhead, Minn	284	26	12.6	1	9.3	28	10.8	3.3
Rio Grande River.								
San Marcial, N. Mex	1,233	11	10.7	7,8	10.4	11,12	10.5	0.3
El Paso, Tex	1,030	14	11.2	24–26	6.8	9,10	8.5	4.4
Snake River.								
Lewiston, Idaho	144	24	9.0	28	5.2	9	6.7	3.8
Riparia, Wash	67	30	9.8	28	5.0	1	7.3	4.8
Columbia River.								
Wenatchee, Wash	473	40	8.5	29,30	7.5	1,2	8.0	1.0
Umatilla, Oreg	270	25	7.8	29	4.2	10,11	5.4	3.6
The Dalles, Oreg	166	40	11.4	30	7.2	1	8.6	4.2
Willamette River.								
Albany, Oreg	118	20	5.0	3	2.9	27	3.7	2.1
Portland, Oreg	12	15	6.6	21,22	4.2	26	5.2	2.4
Sacramento River.								
Red Bluff, Cal	265	23	7.8	1	5.8	25,26	6.6	2.0
Colusa, Cal	156	28	17.5	1	13.5	27,30	15.1	4.0
Knights Landing, Cal	99	18	15.6	5	14.3	28	14.8	1.3
Sacramento, Cal	64	25	20.1	21	18.6	4	19.3	1.5
San Joaquin River.								
Pollasky, Cal	203	10	4.0	18,19,28,30	1.0	1,2	2.5	3.0
Firebaugh, Cal	148	14	8.4	30	3.1	3	5.7	5.3
Lathrop, Cal	49	14	15.7	30	10.6	2,3	13.2	5.1

Figures in parenthesis indicate number of days river was frozen during the month.

Honolulu, T. H., latitude 21° 19′ north, longitude 157° 52′ west; barometer above sea, 38 feet; gravity correction, —0.057 inch, applied. April, 1909.

Day.	Pressure, in inches.*		Air temperature, degrees Fahrenheit.				Moisture.				Wind, in miles per hour.				Precipitation, inches.		Clouds.					
							8 a. m.		8 p. m.		8 a. m.		8 p. m.				8 a. m.			8 p. m.		
	8 a. m.	8 p. m.	8 a. m.	8 p. m.	Maximum.	Minimum.	Wet.	Relative humidity.	Wet.	Relative humidity.	Direction.	Velocity.	Direction.	Velocity.	8 a. m.	8 p. m.	Amount.	Kind.	Direction, from.	Amount.	Kind.	Direction, from.
							°	%	°	%												
1	30.05	30.02	72.8	70.5	77	67	64.1	62	65.0	74	e.	7	ne.	5	0.03	0.00	5 1	Ci. Cu.-n.	nw. e.	3 3	A.-s. Cu.	w. ne.
2	30.04	30.03	71.0	64.0	75	62	65.0	72	61.0	84	n.	4	sw.	8	T.	0.50	5 1	Ci.-s. Cu.-n.	sw. e.	10	S.	n.
3	30.04	30.07	67.0	64.0	71	63	58.0	58	58.5	72	ne.	17	ne.	10	0.01	0.00	2 1	Ci. Cu.	w. 0	10	S.-cu.	ne.
4	30.10	30.05	66.2	66.0	73	60	58.0	60	59.0	66	ne.	14	ne.	15	0.00	0.00	1 Few	A.-s. Cu.	0(?) 0(?)	3 4	A.-s. S.-cu.	w. ne.
5	30.07	30.06	70.0	67.0	74	62	60.9	55	59.0	62	ne.	9	ne.	12	0.00	0.00	2	A.-s.	w.	2	A.-s.	w.
6	30.11	30.09	70.0	68.5	75	64	59.5	53	62.0	70	ne.	12	ne.	4	0.00	0.00	3	A.-cu.	0	Few	S.-cu.	ne.
7	30.13	30.09	72.0	72.0	77	66	66.0	78	67.0	77	ne.	3	ne.	3	0.00	0.00	8 Few	A.-cu. Cu.	s. e.	1	Cu.-n.	e.
8	30.12	30.09	74.0	73.0	79	70	64.0	58	67.0	73	e.	8	ne.	5	0.00	0.00	7 1	A.-cu. S.-cu.	sw. 0	0	0	0
9	30.08	30.09	75.0	71.0	78	69	65.4	60	66.0	77	e.	8	ne.	4	0.00	0.00	5 2	Ci.-s. Cu.	e. e.	0	0	0
10	30.12	30.10	74.0	71.0	78	70	66.3	66	64.0	68	e.	8	e.	4	0.00	0.00	6 4	Ci.-s. Cu.	0 e.	0	0	0
11	30.15	30.09	68.4	70.0	76	67	63.1	75	64.0	72	e.	16	e.	15	T.	0.02	10	S.-cu.	e.	2	Cu.-n.	e.
12	30.09	30.03	73.0	70.0	76	67	61.0	49	63.0	68	ne.	7	ne.	9	T.	T.	3	Cu.	e.	9	A.-s.	w.
13	30.02	30.01	73.1	70.0	76	68	63.1	57	66.0	81	n.	5	ne.	2	0.00	0.00	3 4	Ci.-s. Cu.	w. ne.	0	0	0
14	30.01	29.98	73.2	71.0	76	65	66.0	68	64.0	68	w.	4	ne.	3	0.00	0.00	3 1	Ci.-cu. Cu.	w. ne.	0	0	0
15	30.01	29.99	72.8	72.0	75	64	66.0	70	67.0	77	se.	4	ne.	3	0.00	0.00	3 1	A.-cu. Cu.	se. ne.	5	A.-s.	0(?)
16	30.04	30.01	75.0	72.0	77	66	64.3	55	67.0	77	se.	5	ne.	3	0.00	0.00	3	Ci.	w.	1	A.-s.	0(?)
17	30.03	30.03	73.4	72.0	76	69	67.1	72	68.0	82	se.	3	se.	3	0.00	0.00	6 3	Ci.-cu. Cu.	sw. se.	10	S.	s.
18	30.09	30.11	72.4	73.0	76	70	71.0	89	71.0	91	se.	10	se.	2	T.	T.	10	N.	se.	10	S.	e.
19	30.12	30.11	76.0	72.5	78	68	67.2	63	68.0	80	ne.	8	ne.	2	T.	T.	9 Few	A.-cu. Cu.	w. e.	9	S.	e.
20	30.10	30.08	73.5	71.5	78	70	67.0	71	67.0	79	se.	4	s.	2	0.02	0.00	3 2	Ci. Cu.	0 ne.	0	0	0
21	30.12	30.10	75.0	70.0	80	68	67.0	66	67.0	86	e.	7	e.	4	0.00	T.	6	Cu.	e.	10	N.	e.
22	30.12	30.11	74.3	70.0	79	68	66.0	64	67.0	86	ne.	10	e.	2	0.08	T.	10	S.-cu.	e.	10	N.	ne.
23	30.10	30.06	75.0	72.0	80	69	66.0	62	66.0	78	e.	15	ne.	15	0.01	0.00	5	Cu.	e.	0	0	0
24	30.04	30.01	77.0	70.5	78	68	66.0	56	66.0	79	ne.	2	e.	3	0.00	0.04	Few 3	Ci.-s. Cu.	0 e.	Few	S.-cu.	e.
25	30.01	30.00	73.0	72.0	77	67	68.0	78	67.0	77	ne.	2	se.	8	0.01	0.00	10	S.-cu.	0	4	Cu.	sw.
26	30.04	30.05	74.2	75.0	78	70	70.0	81	71.0	82	se.	14	s.	7	0.00	0.00	2 1	A.-cu. Cu.-n.	s. 0	10	S.	e.
27	30.07	30.05	75.2	70.0	77	68	70.8	80	68.0	90	s.	9	n.	4	0.01	0.26	9 1	A.-s. Cu.-n.	w. 0	10	A.-s.	n.
28	30.04	30.03	75.0	71.5	78	69	70.0	78	67.0	79	se.	5	e.	9	0.01	0.00	10 Few	A.-s. Cu.	sw. 0	5	Cu.	ne.
29	30.05	30.09	76.6	73.0	79	69	69.1	69	67.5	75	n.	2	e.	4	0.00	0.03	7	Cu.	e.	10	Cu.	ne.
30	30.14	30.13	73.4	72.0	82	69	67.0	71	67.0	77	ne.	3	ne.	9	0.00	0.00	10	S.-cu.	ne.	4	Cu.	ne.
31																						
Mean	30.075	30.059	73.1	70.6	77.0	67.1	65.4	66.4	65.6	76.7	ne.	7.5	ne.	5.8	0.18	0.85	6.5	Cu.	e.	4.8	A.-s.	ne.

Observations are made at 8 a.m. and 8 p. m., local standard time, which is that of 157° 30′ west, and is 5h and 30m slower than 75th meridian time. *Pressure values are reduced to sea level and standard gravity.

RAINFALL IN JAMAICA.

Through the kindness of Mr. Maxwell Hall, meteorologist to the government of Jamaica and now in charge of the meteorological service of that island, we have received the following data:

The rainfall over the island for April was therefore an inch below the average.

The greatest rainfall, 16.45 inches, was recorded at Pepper; and no rain fell at Dry Harbor.

Comparative table of rainfall.

[Based upon the average stations only.]

APRIL, 1909.

Divisions.	Relative area.	Number of stations.	Rainfall.	
			1909.	Average.
Northeastern division	25	17	4.19	5.89
Northern division	22	41	1.47	3.29
West-central division	26	20	5.03	7.36
Southern division	27	26	3.88	3.77
Means	100		3.64	5.08

Chart I. Hydrographs for Seven Principal Rivers of the United States, April, 1909.

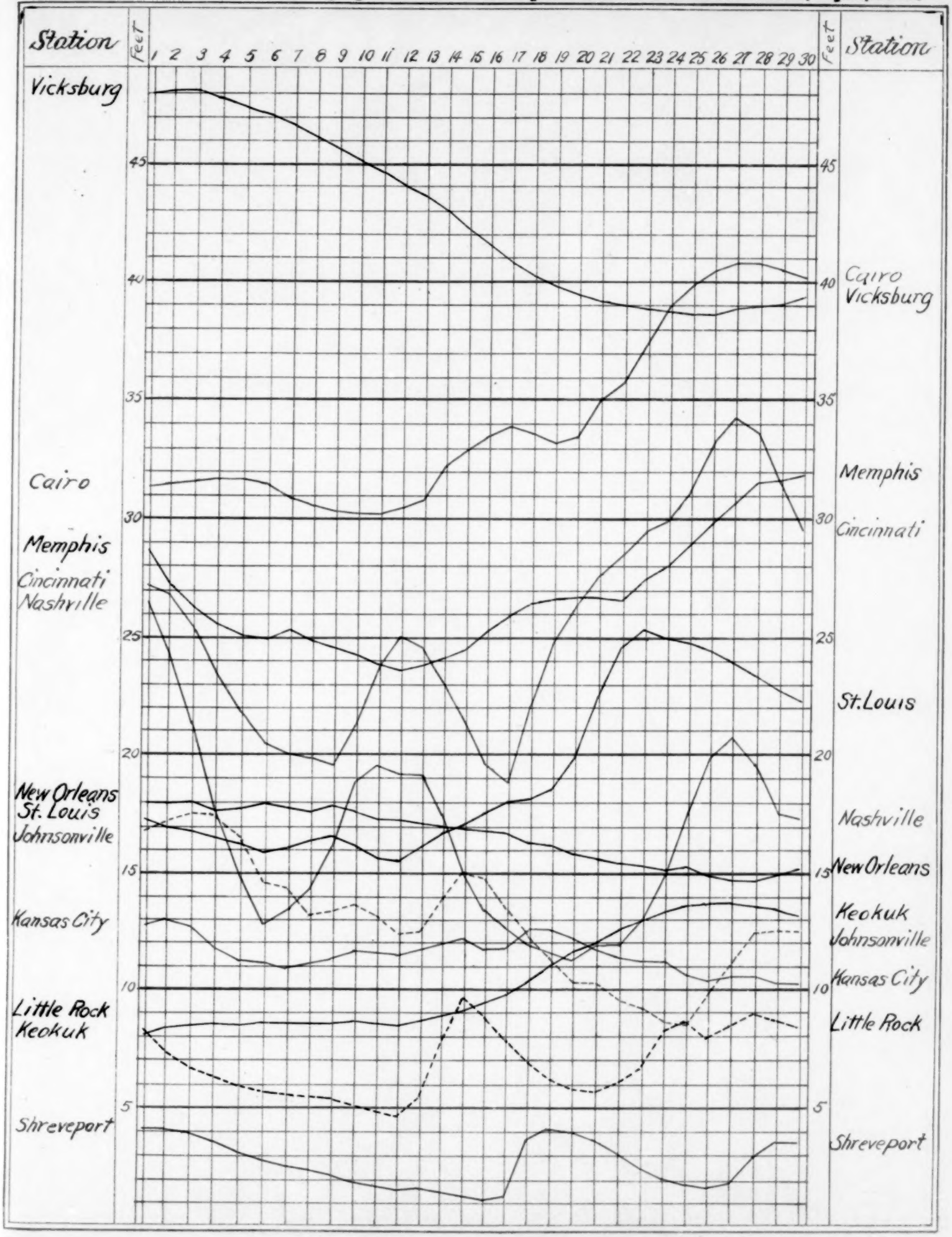
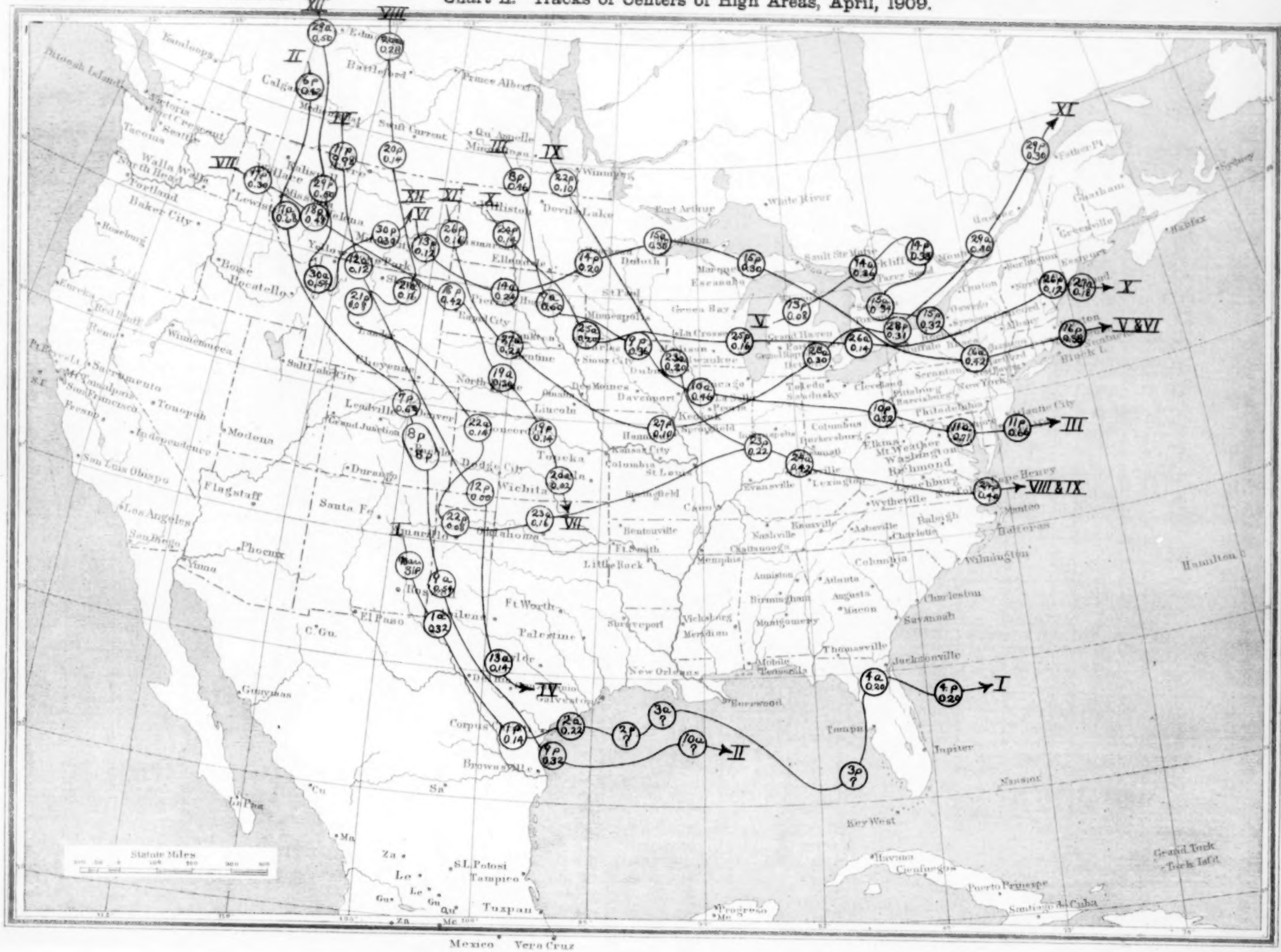


Chart II. Tracks of Centers of High Areas, April, 1909.



Barkerville

Mexico Vera Cruz

Chart III. Tracks of Centers of Low Areas, April, 1909.

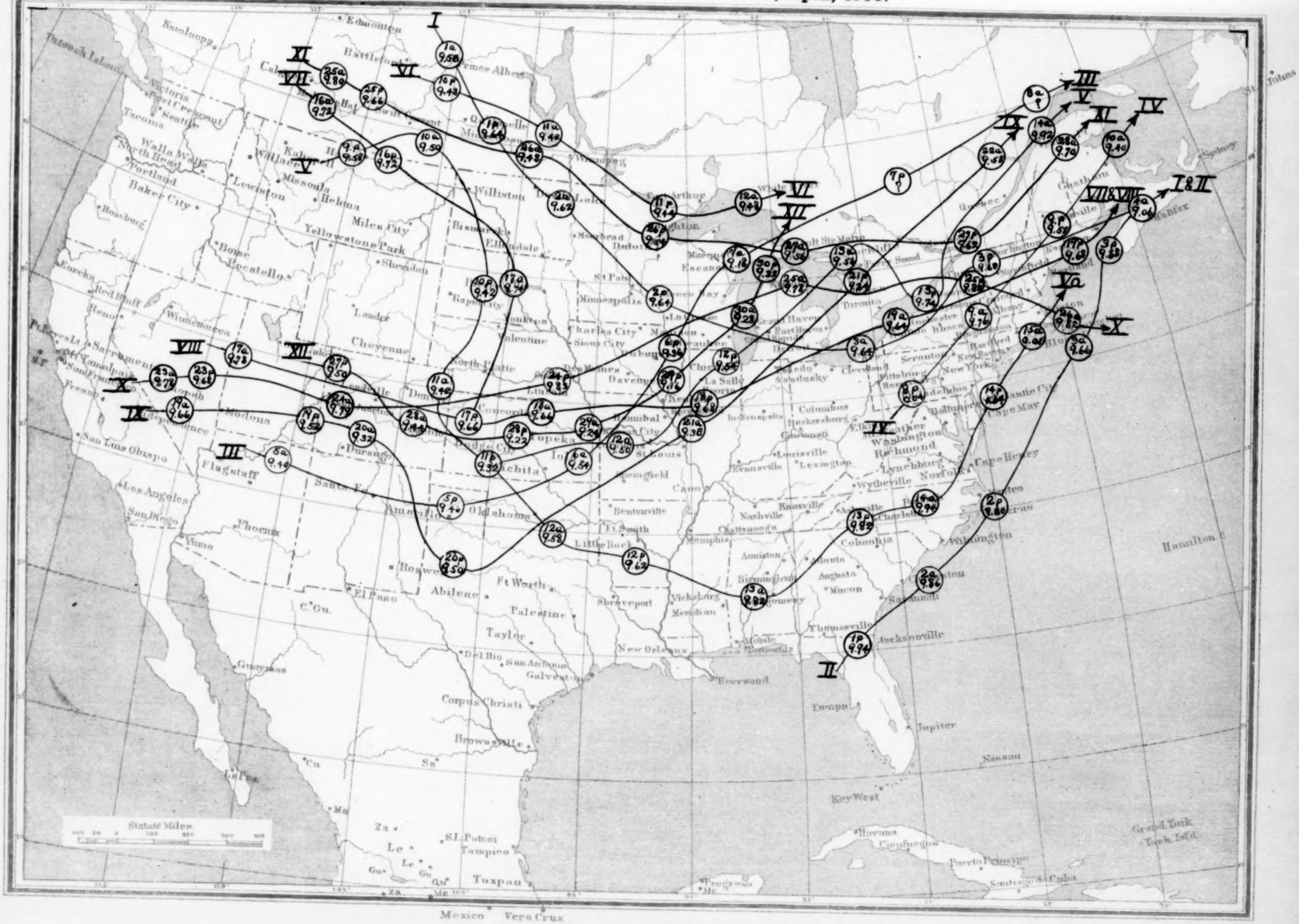
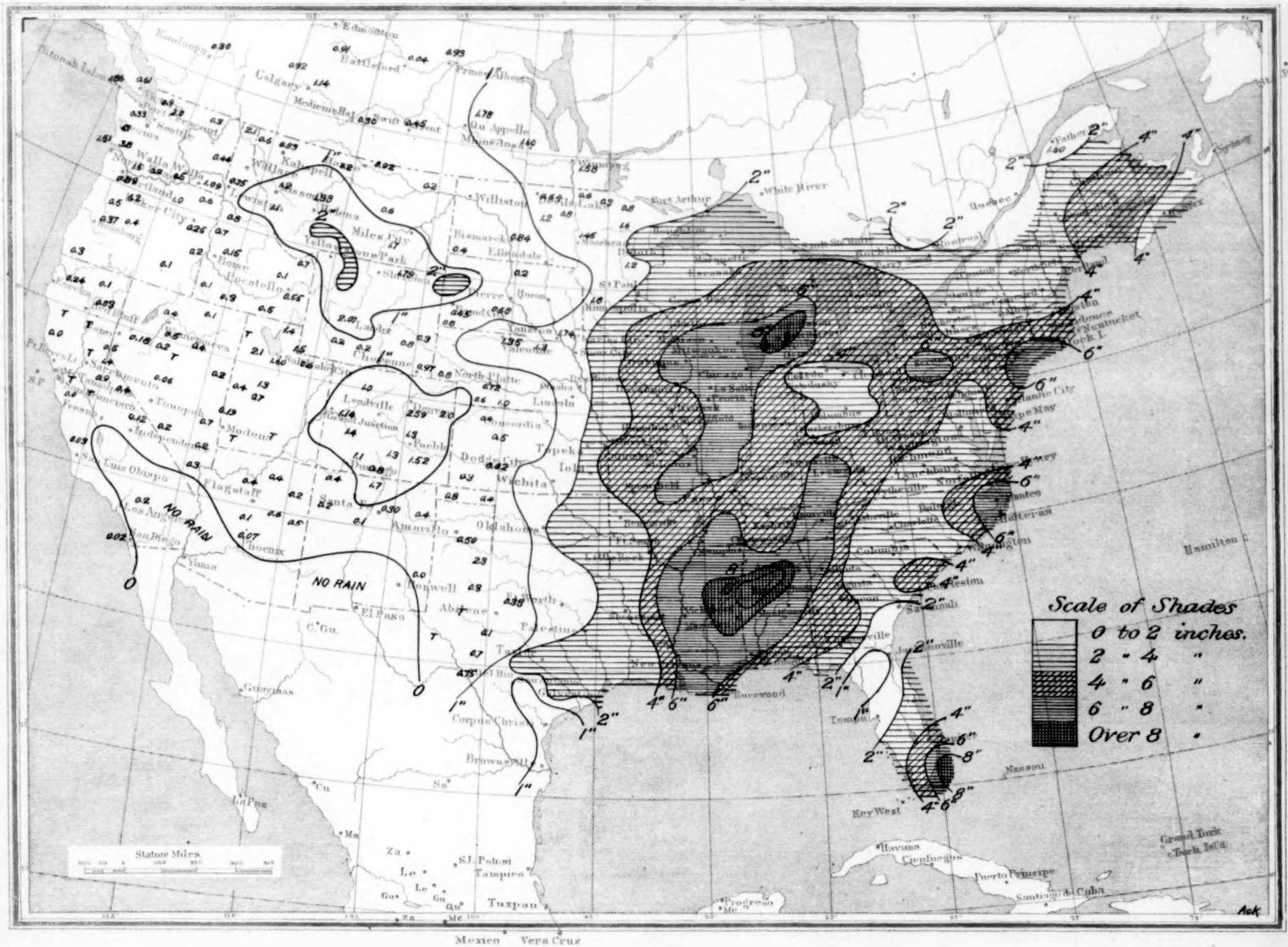


Chart IV. Total Precipitation, April, 1909.



Barkerville

Chart V. Percentage of Clear Sky between Sunrise and Sunset, April, 1909.

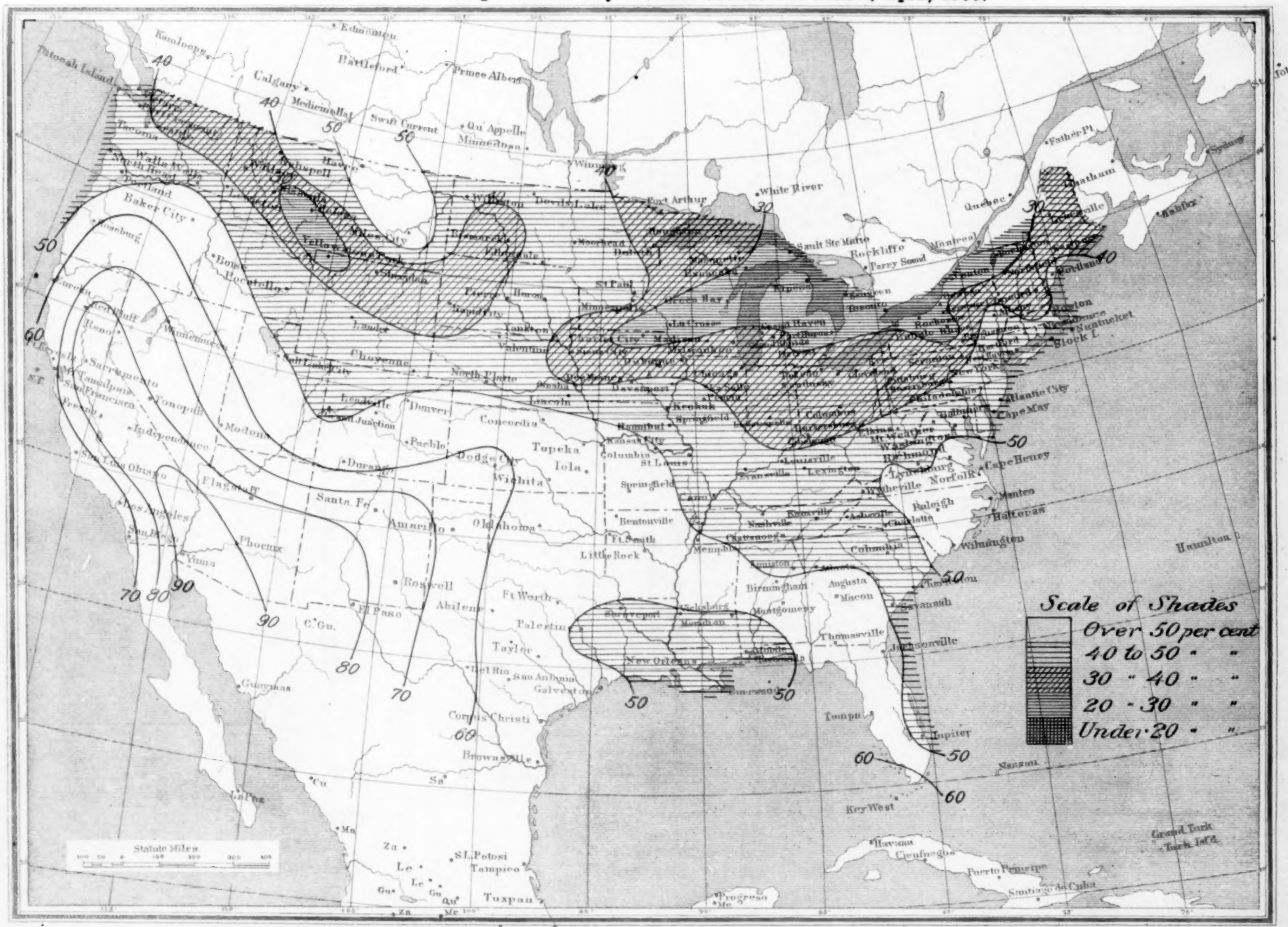


Chart VI. Isobars and Isotherms at Sea Level; Prevailing Winds, April, 1909.

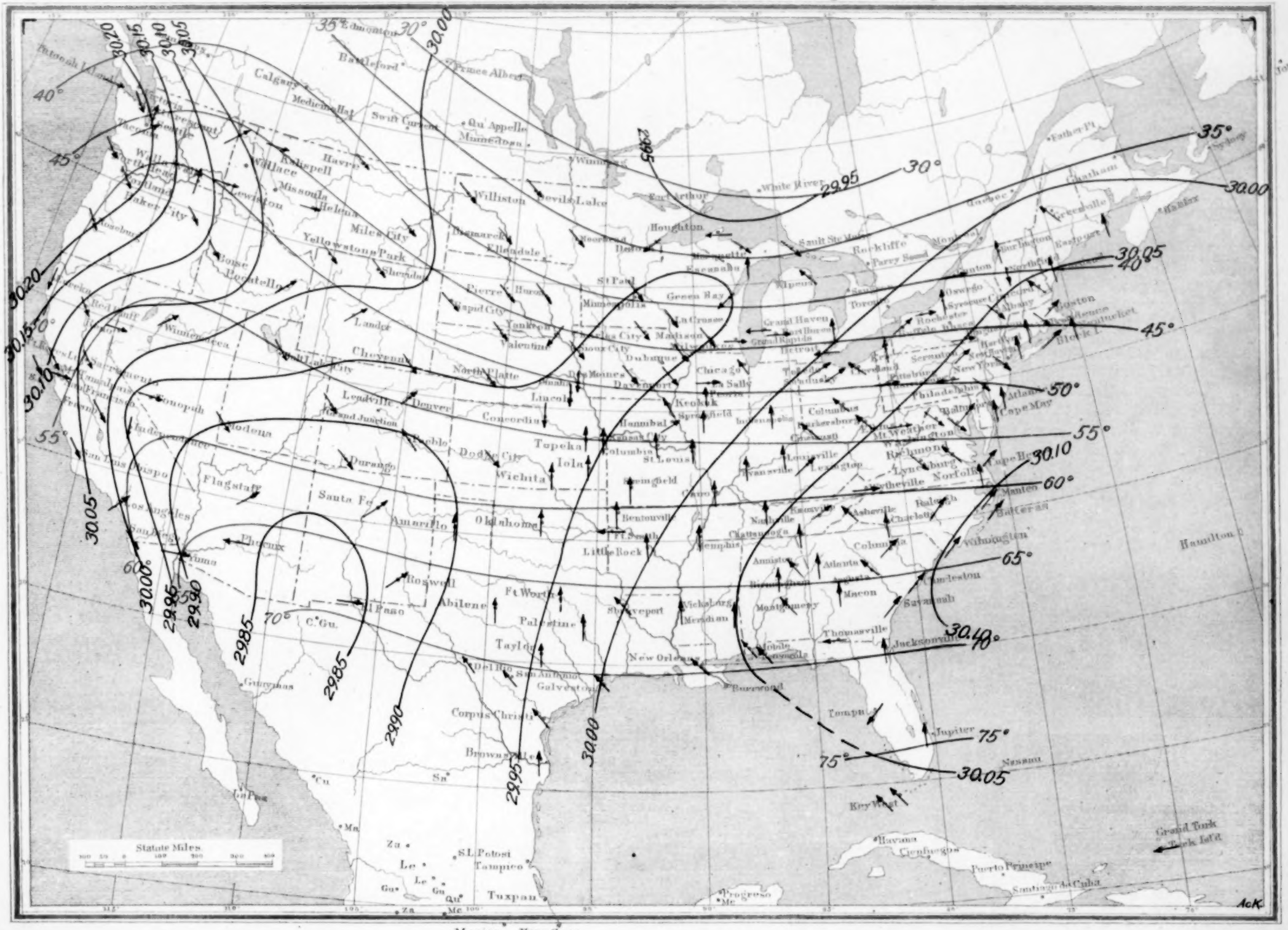


Chart VII. Total Snowfall for April, 1909.

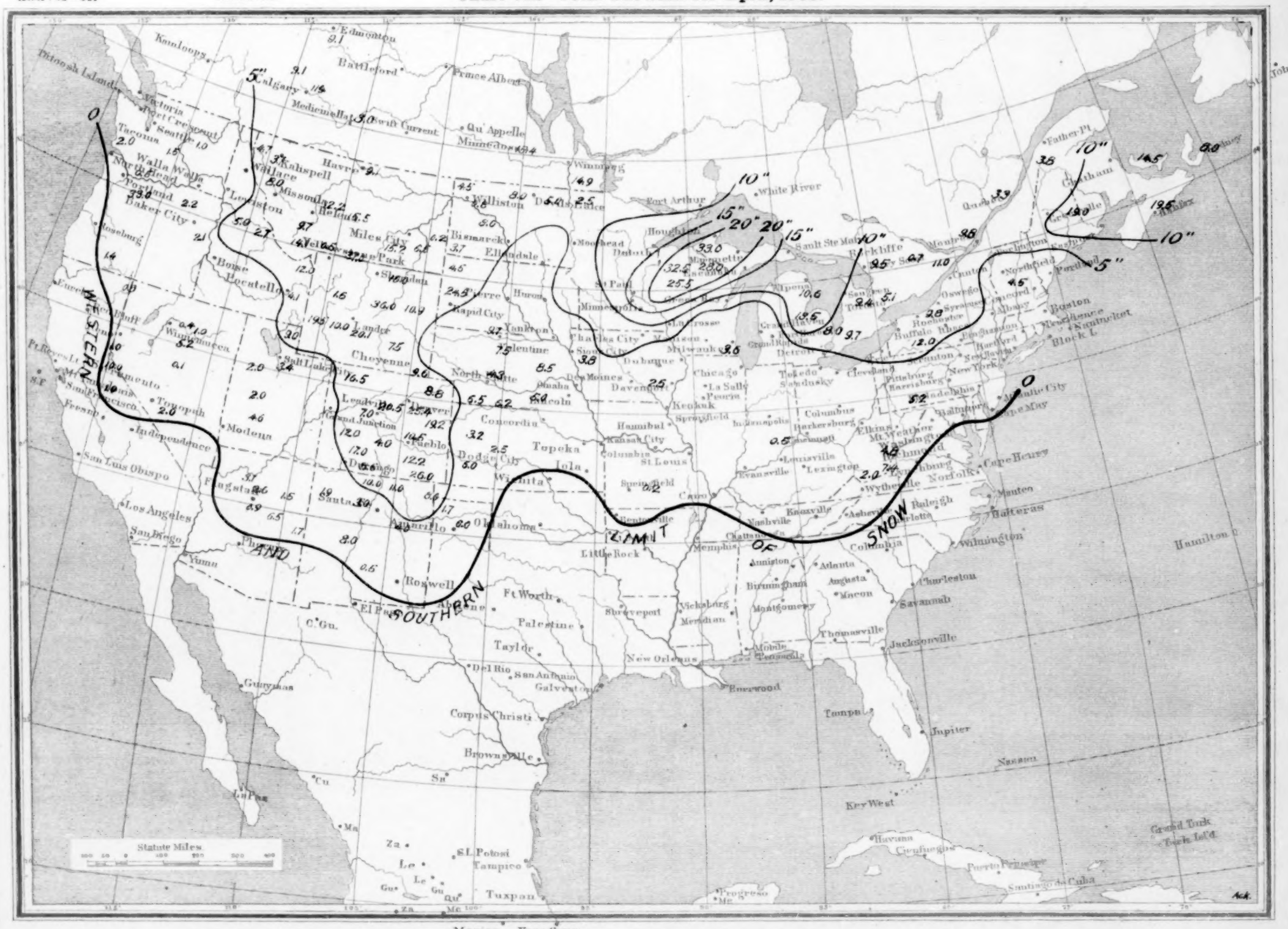

0
5"
10"
15"
20"
20"
15"
10"
10"
5"
10"
0
SOUTHERN LIMIT OF SNOW AND
Statute Miles
Barkerville
Edmonton
Kamloops
Battleford
Prince Albert
Calgary
Victoria
Port Crescent
Tacoma
Seattle
Medicine Hat
Swift Current
Qu'Appelle
Winnipeg
Walla Walla
Kalispell
Havre
Wallace
Missoula
Helena
Williston
Portland
Baker City
Roseburg
Miles City
Bismarck
Bozeman
Boise
Pocatello
Rapid City
Pierre
Huron
Minneapolis
St Paul
Yankton
Lander
Cheyenne
Salt Lake City
Winnemucca
Sacramento
San Francisco
Fresno
Independence
Modena
Grand Junction
Pueblo
Concordia
Topeka
Dodge City
Wichita
Omaha
Lincoln
Des Moines
Davenport
Chicago
La Salle
Peoria
Keokuk
Springfield
Hannibal
Kansas City
Columbia
St Louis
Cairo
Bentonville
Little Rock
Memphis
Amarillo
Oklahoma
Roswell
Los Angeles
San Diego
Yuma
Ft Worth
Abilene
Palestine
Taylor
Del Rio
San Antonio
Galveston
Corpus Christi
Brownsville
Eagle Pass
Guaymas
El Paso
Vicksburg
Meridian
Shreveport
Montgomery
New Orleans
Mobile
Pensacola
Thomasville
Tallahassee
Jacksonville
Tampa
Jupiter
Key West
Havana
Cienfuegos
Puerto Principe
Santiago de Cuba
Progreso
Tuxpan
Tampico
San Luis Potosi
Monterey
Laredo
Nassau
Grand Turk
Turks Isl'd
Caicos Isl'ds
Hamilton
Bermuda
Cape Henry
Norfolk
Wilmington
Charleston
Savannah
Augusta
Macon
Atlanta
Anniston
Birmingham
Knoxville
Nashville
Evansville
Louisville
Lexington
Cincinnati
Columbus
Zanesville
Wheeling
Pittsburg
Harrisburg
Philadelphia
Baltimore
Cape May
Atlantic City
Block I.
Providence
Boston
Nantucket
Albany
Syracuse
Rochester
Buffalo
Oswego
Northfield
Portland
Gratham
Father Pt
Quebec
Montreal
Ottawa
Kingston
Toronto
Port Arthur
White River
Sault Ste Marie
Houghton
Marquette
Escanaba
Duluth
Moorhead
Milwaukee
Grand Rapids
Detroit
Toledo
Sandusky
Cleveland
Buffalo
Rochester
Syracuse
Oswego
Albany
Boston
Providence
Nantucket
Block I.
Portland
Northfield

Chart VIII. Depth of Snow on Ground, April 30, 1909.

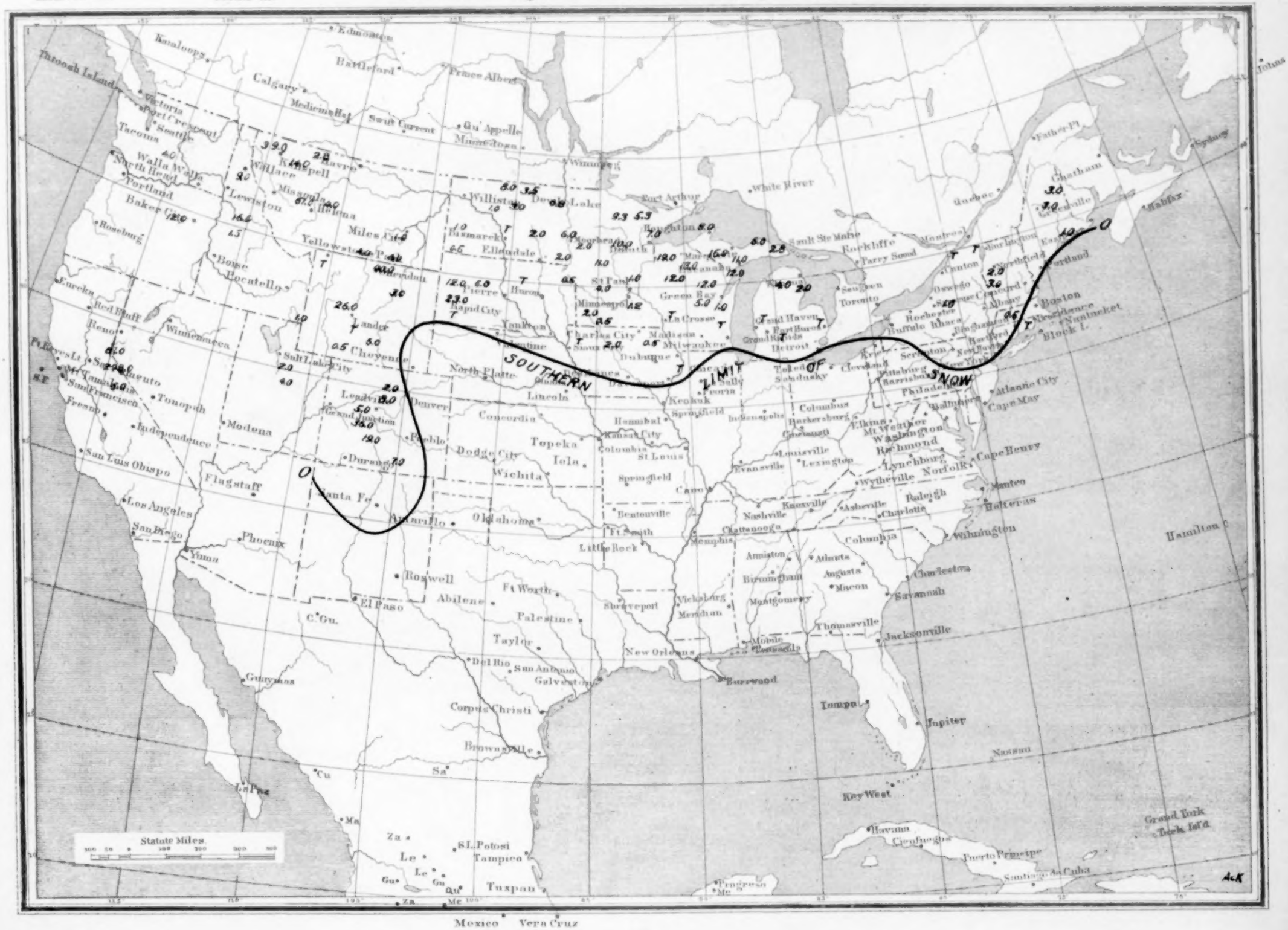


Chart IX. Cloudbelts of Venus.

FIG. 2.—Hypothetical sketch of Venus, with her axis making a large angle with the plane of her orbit.

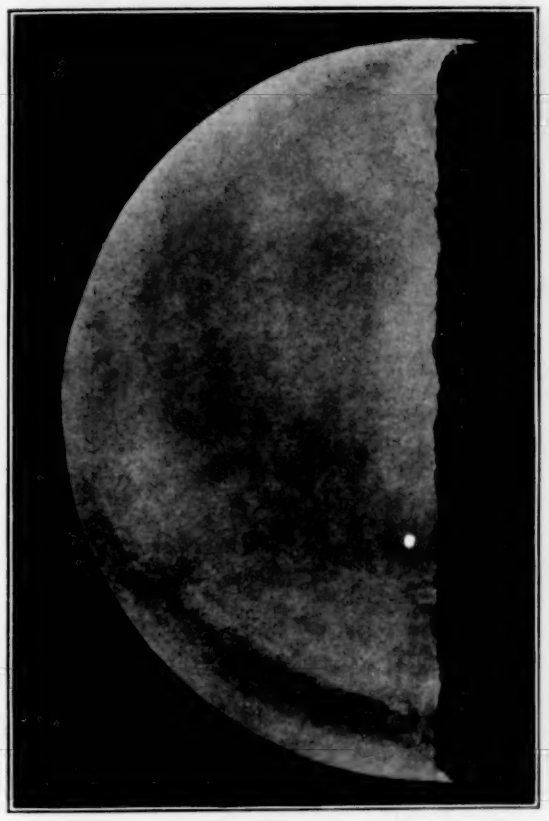


FIG. 3.—Hypothetical sketch of Venus, with her axis inclined 35° to the ecliptic and the warmer pole toward the observer.

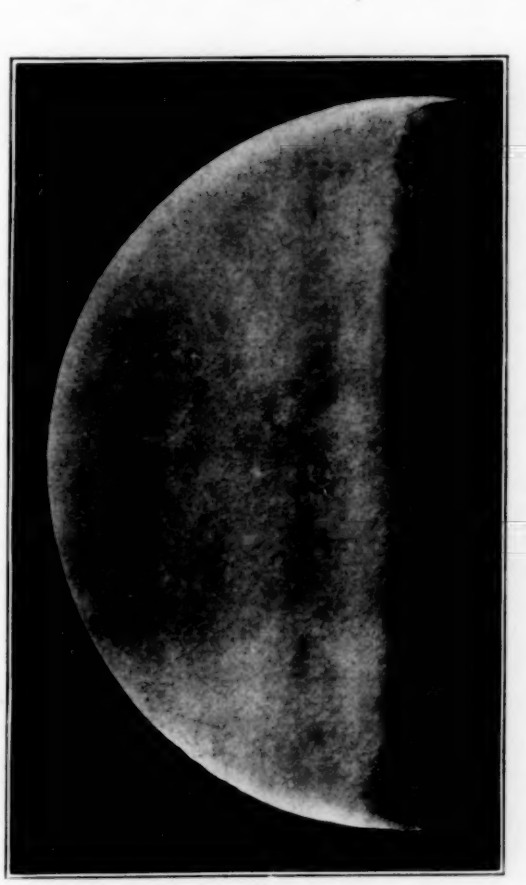


FIG. 4.—Venus as seen.

FIG. 5.—Venus as seen.

Note the faint band of shade approximately parallel to, but at some distance from the terminator.